Learning Outcomes based Curriculum Framework (LOCF)

for

(B.Sc. with Chemistry)

Undergraduate Programme

2020

UNIVERSITY GRANTS COMMISSION

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NEW DELHI – 110 002

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.

DPSingh

New Delhi
30th July, 2019

(Prof. D. P. Singh)
Chairman
University Grants Commission

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Preamble

Over the past decades the higher education system of our country has undergone substantial structural and functional changes resulting in both quantitative and qualitative development of the beneficiaries. Such changes have gained momentum with the introduction of Choice Based Credit System (CBCS) which further expects learning outcome based curriculum in order to maximize the benefits of the newly designed curriculum. The learning outcome based curriculum in general and in Chemistry in particular will definitely help the teachers of the discipline to visualize the curriculum more specifically in terms of the learning outcomes expected from the students at the end of the instructional process. It is pertinent to mention here that the purpose of education is to develop an integrated personality of the individual and the educational system provides all knowledge and skills to the learner for this.

The Learning outcome-based curriculum framework (LOCF) has been prepared to support designing uniform, advanced and effective Chemistry curriculum for undergraduate studies in Chemistry. The recommendations related to curriculum development is applicable for college/university education system which includes heads of schools/departments, practising teachers, parents, employers, academics from tertiary institutions, professionals from related fields or related bodies and representatives from university/college examinations authorities. The LOCF guides are based on the consultation documents on curriculum framework of University Grants Commission and MOOCs. The concerns, needs and interests of students, teachers as well as societal expectations has been taken into consideration while developing these framework structure. Each subject content aims to present a curriculum framework, specifying the curriculum aims, learning targets and objectives, and thus providing suggestions regarding curriculum planning, learning and teaching strategies, assessment and resources. In addition, the curriculum framework also provides examples of effective learning, teaching and assessment practices. A coherent understanding of the whole-undergraduate chemistry (major and pass) curriculum planning and the planning of student learning ability at subject levels can be established. Curriculum development is a collaborative and an on-going enhancement process, therefore, the same shall be updated and improved from time to time to meet new needs of students, teachers and society at large.

The template as developed has the provision of ensuring the integrated personality of the students in terms of providing opportunity for exposure to the students towards core courses, discipline specific courses, generic elective courses, ability enhancement courses and skill enhancement courses with special focus on technical, communication and subject specific skills through practical and other innovative transactional modes to develop their employability skills. The template of learning outcome based curriculum has categorically mentioned very well defined expected outcomes for the programme like core competency, communication skills, critical thinking, affective skills, problem-solving, analytical, reasoning, research-skills, teamwork, digital literacy, moral and ethical awareness, leadership readiness and so on along with very specific learning course outcomes at the starting of each course. Therefore, this template on Learning Outcomes based Curriculum Framework (LOCF) for B.Sc. with Chemistry/Chemistry Honors will definitely be a landmark in the field of outcome based curriculum construction.

2. Foreword

Quality of higher education is considered as a critical requirement for enabling effective participation of young people in acquiring knowledge which in turn improve young people skill, national and global competiveness. Learning outcomes-based curriculum framework (LOCF) planning for Bachelor degree programme in Chemistry/Chemistry (Honours) is a novel approach towards teaching in terms of imparting knowledge, understanding, skill, attitudes and values to undergraduate students, in particular. In this context, the course/curriculum has been designed to provide in- depth knowledge in core discipline of chemistry with special emphasis on use of technology in chemical applications. Further, the generic discipline subjects has been framed to overall improve the students' capability in other allied discipline of sciences as well as technology. It is understood that the outcome of the curriculum frame-work can be helpful in enhancing employability of graduates in various sectors, both private and public, in addition to enhancing self-employable, entrepreneurship characteristics among graduate thus raising the quality of teaching and research outcomes in higher educational institutes. The integration of teaching and learning process can further articulate the essential societal learning that can promote the improvement in practical use of knowledge and investment in higher education with targeted and effective equity-related initiative.

1. Introduction

Academics and research in India is a priority which depends upon the quality of education. Quality higher education include innovations that can be useful for efficient governance of higher education institutions, systems and society at large. Thus, fundamental approach to learning outcome-based curriculum framework emphasizes upon demonstration of understanding, knowledge, skills, attitudes and values in particular programme of study. The LOCF based programme intended to follow flexibility and innovation in design of the programme, its assessment, and expect graduate attributes demonstrating the level of learning outcome. It is further expected to provide effective teaching – learning strategies including periodic review of the programme and its academic standard. The learning outcome-based curriculum framework for B.Sc. degree in Chemistry is intended to provide a broad framework and hence designed to address the needs of the students with chemistry as the core subject of study. The framework is expected to assist in the maintenance of the standard of chemistry degrees/programmes across the country and periodic programme review within a broad framework of agreed/expected graduate attributes, qualification descriptors, programme learning outcomes and course-level learning outcomes. The framework is intended to allow flexibility and innovation in programme design, syllabi development, teaching-learning process and quality assessment of students learning levels.

This curriculum framework for the bachelor-level program in Chemistry is developed keeping in view of the student centric learning pedagogy, which is entirely outcome-oriented and curiosity-driven. To avoid rote-learning approach and foster imagination, the curriculum is more leaned towards self-discovery of concepts. The curriculum framework focuses on pragmatist approach whereby practical application of theoretical concepts is taught with substantial coverage of practical and field works. The platform aims at equipping the graduates with necessary skills for Chemistry-related careers, careers with general graduate-level aptitude and for higher education in Chemistry and allied subjects. Augmented in this framework are graduate attributes including critical thinking, basic psychology, scientific reasoning, moral ethical reasoning and so on, qualification descriptors that are specific outcomes pertinent to the discipline of chemistry, learning outcomes for the two programmes these frameworks have been developed, learning outcomes for individual courses, pedagogical methods and assessment methods. While designing these frameworks, emphasis is given on the objectively measurable teaching-learning outcomes to ensure employability of the graduates. In line with recent trends in education section, these frameworks foster implementation of modern pedagogical tools and concepts such as flip-class, hybrid learning, MOOCs and other e-learning platforms. In addition, the framework pragmatic to the core; it is designed such a way to enable the learners implementing the concepts to address the real world problems. A major emphasis of these frameworks is that the curriculum focuses on issues pertinent to India and also of the west; for example, green chemistry and biomaterials etc. Above all, these frameworks are holistic and aim to mould responsible Indian citizen to have reflective thinking, scientific temper, and digital literacy in order to acquire requisite skill to be self employed entrepreneurial.

Aims:

2. To transform curriculum into outcome-oriented scenario
3. To develop the curriculum for fostering discovery-learning
4. To equip the students in solving the practical problems pertinent to India
5. To adopt recent pedagogical trends in education including e-learning, flipped class, hybrid learning and MOOCs
6. To mold responsible citizen for nation-building and transforming the country towards the future

2. Learning Outcome Based Curriculum Vis- A -Vis Objective Based Curriculum:

Curriculum is the heart of any educational system. It can be focused either to achieve the objectives of each course of the programme or on the expected learning outcomes from each course. The objective based curriculum refers to the overall targets to be achieved through curriculum which may be long term or immediate. On the other hand, the learning outcome based curriculum is very specific in nature in terms of changes in the cognitive, affective and psychomotor behavior of the students as a result of their exposure to the curriculum. The outcome based curriculum provides the teacher very specific targets which he can achieve through the selected instructional process as compared to the objective based curriculum which provides general outcomes.

The learning outcome based curriculum has very close relationship with the learning of the students whereas objective based curriculum focusses on only providing knowledge to the students. In other words, higher cognitive skills are developed through learning outcome based curriculum. Hence, it is preferred to develop learning outcome based curriculum which will provide specific directions to the teacher with respect to the transaction process and expected changes in the behavior of the students as well.

a. Nature and extent of the B.Sc Chemistry Programme

Chemistry is referred to as the science that systematically study the composition, properties, and reactivity of matter at atomic and molecular level. The scope of chemistry is very broad. The key areas of study of chemistry comprise Organic chemistry, Inorganic Chemistry, Physical Chemistry and Analytical Chemistry. Organic chemistry deals with study of substances containing carbon mostly; inorganic chemistry deals with study of all other elements/compounds/substances and their chemical properties. Physical chemistry deals with applications of concepts, laws to chemical phenomena. Analytical chemistry, in general, deals with identification and quantification of materials. Development of new interdisciplinary subjects like nano-materials, biomaterials, etc. and their applications from chemistry point of view added new dimension to materials chemistry. Thus, the degree programme in chemistry also intended to cover overlapping areas of chemistry with physics, biology, environmental sciences. Further, a broad range of subjects such as materials chemistry, biomaterials, nano-materials, environmental chemistry, etc., has also been introduced which can be helpful for students/faculty members to broaden the scope of their studies and hence applications from job prospective point of view. Therefore, as a part of efforts to enhance employability of graduates of chemistry, the curricula also include learning experience with industries and research laboratories as interns. In addition, industrial visits/industrial projects are encouraged and added to the curriculum in order to enhance better exposure to jobs/employment opportunities in industries, scientific projects and allied sectors.

This modified syllabus has been drafted to enable the students to equip for national level competitive exams that they may attempt in future. To ensure implementation of a holistic pedagogical model, several allied disciplines are covered/introduced in this framework, including Physics, Mathematics, Biology and a number of generic, and ability enhancement electives. In addition, employability of B.Sc. Chemistry graduate is given due importance such that their core competency in the subject matter, both theoretical and practical, is ensured. To expand the employability of graduates, a number of skill development courses are also introduced in this framework.

b. Aims of Bachelor's degree programme in Chemistry

The broad aims of bacheleors degree programme in Chemistry are:

The aim of bachelor's degree programme in chemistry is intended to provide:

(i).Broad and balance knowledge in chemistry in addition to understanding of key chemical concepts, principles and theories.

(ii).To develop students' ability and skill to acquire expertise over solving both theoretical and applied chemistry problems.

(iii). To provide knowledge and skill to the students' thus enabling them to undertake further studies in chemistry in related areas or multidisciplinary areas that can be helpful for self-employment/entrepreneurship.

(iv).To provide an environment that ensures cognitive development of students in a holistic manner. A complete dialogue about chemistry, chemical equations and its significance is fostered in this framework, rather than mere theoretical aspects

(v).To provide the latest subject matter, both theoretical as well as practical, such a way to foster their core competency and discovery learning. A chemisry graduate as envisioned in this framework would be sufficiently competent in the field to undertake further discipline-specific studies, as well as to begin domain-related employment.

(vi).To mould a responsible citizen who is aware of most basic domain-independent knowledge, including critical thinking and communication.

(vii).To enable the graduate prepare for national as well as international competitive examinations, especially UGC-CSIR NET and UPSC Civil Services Examination.

3. Program Learning Outcomes

The student graduating with the Degree B.Sc (Honours) Chemistry should be able to acquire

- **Core competency:** Students will acquire core competency in the subject Chemistry, and in allied subject areas.

(i). Systematic and coherent understanding of the fundamental concepts in Physical chemistry, Organic Chemistry, Inorganic Chemistry, Analytical Chemistry and all other related allied chemistry subjects.

(ii).Students will be able to use the evidence based comparative chemistry approach to explain the chemical synthesis and analysis.

(iii).The students will be able to understand the characaterizについては of materials.

(iv). Students will be able to understand the basic principle of equaipments, instruments used in the chemistry laboratory.

(v).Students will be able to demonstrate the experimental techniques and methods of their area of specialization in Chemisry.

(vi). ***Disciplinary knowledge and skill***: A graduate student is expected to be capable of demonstrating comprehensive knowledge and understanding of both theoretical and experimental/applied chemistry knowledge in various fields of interest like Analytical Chemistry, Physical Chemistry, Inorganic Chemistry, Organic Chemistry, Material Chemistry, etc. Further, the student will be capable of using of advanced instruments and related soft-wares for in-depth characterization of materials/chemical analysis and separation technology.

(vii). ***Skilled communicator***: The course curriculum incorporates basics and advanced training in order to make a graduate student capable of expressing the subject through technical writing as well as through oral presentation.

(viii). ***Critical thinker and problem solver***: The course curriculum also includes components that can be helpful to graduate students to develop critical thinking ability by way of solving problems/numerical using basic chemistry knowledge and concepts.

(ix). ***Sense of inquiry***: It is expected that the course curriculum will develop an inquisitive characteristics among the students through appropriate questions, planning and reporting experimental investigation.

(x). ***Team player***: The course curriculum has been designed to provide opportunity to act as team player by contributing in laboratory, field based situation and industry.

(xi). ***Skilled project manager***: The course curriculum has been designed in such a manner as to enabling a graduate student to become a skilled project manager by acquiring knowledge about chemistry project management, writing, planning, study of ethical standards and rules and regulations pertaining to scientific project operation.

(xii). ***Digitally literate***: The course curriculum has been so designed to impart a good working knowledge in understanding and carrying out data analysis, use of library search tools, and use of chemical simulation software and related computational work.

(xiii). ***Ethical awareness/reasoning***: A graduate student requires to understand and develop ethical awareness/reasoning which the course curriculum adequately provide.

(xiv). ***Lifelong learner***: The course curriculum is designed to inculcate a habit of learning continuously through use of advanced ICT technique and other available techniques/books/journals for personal academic growth as well as for increasing employability opportunity.

4. Course Learning Outcomes

The course learning outcomes are aligned with program learning outcomes but these are specific-to-specific courses offered in a program. The course level learning shall be reflected as program level learning. The core courses shall be the backbone of this framework whereas discipline electives, generic electives and skill enhancement courses would add academic excellence in the subject together with multi-dimensional and multidisciplinary approach.

In course learning outcomes, the student will attain subject knowledge in terms of individual course as well as holistically. The example related to core courses and their linkage with each other is stated below:

									Core Course (CC)									
Programme Outcomes	**CC1**	**CC2**	**CC3**	**CC4**	**CC5**	**CC6**	**CC7**				**CC8**	**CC9**	**CC10**	**CC11**	**CC12**	**CC13**	**CC14**	
Core competency	☑	☑	☑	☑	☑	☑	☑				☑	☑	☑	☑	☑	☑	☑	
Critical thinking	☑	☑	☑	☑	☑	☑	☑				☑	☑	☑	☑	☑	☑	☑	
Analytical reasoning	☑	☑	☑	☑	☑	☑	☑				☑	☑	☑	☑	☑	☑	☑	
Research-skills	☑	☑	☑	☑	☑	☑	☑				☑	☑	☑	☑	☑	☑	☑	
Teamwork	☑	☑	☑	☑	☑	☑	☑				☑	☑	☑	☑	☑	☑	☑	

		Discipline elective Courses (DEC)/Discipline Specific Elective (DSE)																
Programme Outcomes	**DSE1**	**DSE-2**	**DSE-3**	**DSE-4**	**DSE-5**	**DSE-6**	**DSE-7**				**DSE-8**	**DSE-9**	**DSE-10**	**DSE-11**	**DSE-12**			
Additional Academic Knowledge	☑	☑	☑	☑	☑	☑	☑				☑	☑	☑	☑	☑			
Problem-solving	☑	☑	☑	☑	☑	☑	☑				☑	☑	☑	☑	☑			
Additional analytical skills	☑	☑	☑	☑	☑	☑	☑				☑	☑	☑	☑	☑			
Additional Research-skills	☑	☑	☑	☑	☑	☑	☑				☑	☑	☑	☑	☑			
		Generic Elective Courses (GEC)																
Programm	**GEC-1**	**GEC-2**	**GEC-3**	**GE**	**GE**	**GE**												

e Outcomes				C-4	C-5	C-6												
Additional Academic Knowledge	☑	☑	☑	☑	☑	☑												
Exposure beyond discipline	☑	☑	☑	☑	☑	☑												
Problem-solving	☑	☑	☑	☑	☑	☑												
Analytical reasoning	☑	☑	☑	☑	☑	☑												

	Ability enhancement Course										
Programme Outcomes	AEC1	AEC 2	AEC 3	AEC 4	AEC 5	AEC 6	AEC 7	AEC 8	AEC 9	AEC10	AEC11
Additional Academic	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

Knowledge											
Psychological skills	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Problem-solving	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
	Skill Enhancement Course (SEC)										
Programme Outcomes	SEC1	SEC 2	SEC 3	SEC 4	SEC 5	SEC 6	SEC 7	SEC 8	SEC 9	SEC 10	SEC 11
Additional Knowledge enhancement	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Exposure beyond discipline	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Analytical reasoning	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Digital	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

Literacy											
Moral and ethical awareness	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

The core courses would fortify the students with in-depth subject knowledge concurrently; the discipline specific electives will add additional knowledge about applied aspects of the program as well as its applicability in both academia and industry. Generic electives will introduce integration among various interdisciplinary courses. The skill enhancement courses would further add additional skills related to the subject as well as other than subject. In brief the student graduated with this type of curriculum would be able to disseminate subject knowledge along with necessary skills to suffice their capabilities for academia, entrepreneurship and Industry.

5. Teaching Learning Outcomes

The learning outcomes based course curriculum framework of Chemistry is designed to persuade the subject specific knowledge as well as relevant understanding of the course. The academic and professional skills required for Chemistry-based professions and jobs are also offered by same course in an extraordinary way. In addition, the learning experiences gained from this course should be designed and implemented for cognitive development in every student. The practical associated with this course helps to develop an important aspect of the teaching-learning process. Various types of teaching and learning processes will need to be adopted to achieve the same. The important relevant teaching and learning processes involved in this course are;

- Class lectures
- Seminars
- Tutorials
- Group discussions and Workshops
- Peer teaching and learning
- Question preparation
- Subjective type
- Long answer
- Short answer
- Objective type
    - Multiple choice questions
    - One answer/two answer type questions
    - Assertion and reasoning
- Practicum, and project-based learning
- Field-based learning
- Substantial laboratory-based practical component and experiments
- Open-ended project work,
- Games
- Technology-enabled learning
- Internship in industry, and research establishments.

The effective teaching strategies will also need to be adopted to develop problem-solving skills, higher-order skills of reasoning and analysis. The designed course also encourages fostering the social values/responsibility for maintaining and protecting the surrounding environment for improved living conditions. A learner centric and active participatory pedagogy shall be introduced in this framework.

6. Learning outcomes- based curriculum framework for B.Sc. Chemisry and B.Sc. Chemistry (Honours)

a) Attributes of a Chemistry Graduate

Attributes of chemistry graduate under the outcome-based teaching-learning framework may encompass the following:

- **Core competency:** The chemistry graduates are expected to know the fundamental concepts of chemistry and applied chemistry. These fundamental concepts would reflect the latest understanding of the field, and therefore, are dynamic in nature and require frequent and time-bound revisions.
- **Communication skills:** Chemistry graduates are expected to possess minimum standards of communication skills expected of a science graduate in the country. They are expected to read and understand documents with in-depth analyses and logical arguments. Graduates are expected to be well-versed in speaking and communicating their idea/finding/concepts to wider audience
- **Critical thinking:** Chemistry graduates are expected to know basics of cognitive biases, mental models, logical fallacies, scientific methodology and constructing cogent scientific arguments.
- **Psychological skills:** Graduates are expected to possess basic psychological skills required to face the world at large, as well as the skills to deal with individuals and students of various sociocultural, economic and educational levels. Psychological skills may include feedback loops, self-compassion, self-reflection, goal-setting, interpersonal relationships, and emotional management.
- **Problem-solving:** Graduates are expected to be equipped with problem-solving philosophical approaches that are pertinent across the disciplines;
- **Analytical reasoning:** Graduates are expected to acquire formulate cogent arguments and spot logical flaws, inconsistencies, circular reasoning etc.
- **Research-skills:** Graduates are expected to be keenly observant about what is going on in the natural surroundings to awake their curiosity. Graduates are expected to design a scientific experiment through statistical hypothesis testing and other *a priori* reasoning including logical deduction.

- **Teamwork:** Graduates are expected to be team players, with productive co-operations involving members from diverse socio-cultural backgrounds.
- **Digital Literacy:** Graduates are expected to be digitally literate for them to enroll and increase their core competency via e-learning resources such as MOOC and other digital tools for lifelong learning. Graduates should be able to spot data fabrication and fake news by applying rational skepticism and analytical reasoning.
- **Moral and ethical awareness:** Graduates are expected to be responsible citizen of India and be aware of moral and ethical baseline of the country and the world. They are expected to define their core ethical virtues good enough to distinguish what construes as illegal and crime in Indian constitution. Emphasis be given on academic and research ethics, including fair Benefit Sharing, Plagiarism, Scientific Misconduct and so on.
- **Leadership readiness:** Graduates are expected to be familiar with decision-making process and basic managerial skills to become a better leader. Skills may include defining objective vision and mission, how to become charismatic inspiring leader and so on.

b) Qualification Descriptors

i. B.Sc. Chemistry (Honours)

The qualification descriptors for a Bachelor's degree in Chemistry (Honours) may include following:

(i). Systematic and fundamental understanding of chemistry as a discipline.

(ii). Skill and related developments for acquiring specialization in the subject.

(iii). Identifying chemistry related problems, analysis and application of data using appropriate methodologies.

(iv). Applying subject knowledge and skill to solve complex problems with defined solutions.

(v). Finding opportunity to apply subject-related skill for acquiring jobs and self-employment.

(vi). Understanding new frontiers of knowledge in chemistry for professional development.

(vii). Applying subject knowledge for solving societal problems related to application of chemistry in day to day life.

(ix). Applying subject knowledge for sustainable environment friendly green initiatives.

(x). Applying subject knowledge for new research and technology.

ii. B.Sc. Chemistry (H) & Chemistry (Pass)

The qualification descriptors for a Bachelor's degree in Chemistry may also include following:

(i).To demonstrate a systematic, extensive and coherent knowledge and understanding of academic fields of study as a whole and its applications and links to disciplinary areas of the study; including critical understanding of the established theories, principles and concepts of a number of advanced and emerging issues in the field of chemistry;

(ii).To demonstrate procedural knowledge that creates different types of professionals in the field of chemistry. Further application of knowledge can enhance productivity of several economically important product. Knowledge of Chemistry is also necessary for the development and management of industry, manufacturing of fine chemicals, etc.

(iii)Developing skills and ability to use knowledge efficiently in areas related to specializations and current updates in the subject

(iv).Demonstrate comprehensive knowledge about chemistry, current research, scholarly and professional literature of advanced learning areas of Chemistry

(v).Use knowledge understanding and skills for critical assessment of wide range of ideas and problems in the field of Chemistry.

(vi).Communicate the results of studies in the academic field of Chemistry using main concepts, constructs and techniques

(vii).Apply one's knowledge and understanding of Chemistry to new/unfamiliar contexts and to identify problems and solutions in daily life.

(viii).To think any apply understanding of the subject of Chemisry, Chemical Sciences sciences in identifying the problems which can be solved through the use of chemistry knowledge.

(ix).To think of the adopting expertise in chemical sciences and solve the problems of environment, green chemistry, ecology, sustainable development, hunger, etc.

c) *Distribution of different types of courses with their credits for B.Sc. Chemistry (Pass Course) (PCM & PCB)*

Semester	Core Courses (CC) Note: 12 CC each with 6 credits, (total no. of papers 12), 4 corec courses are compulsory to be selected from each subject A, B, C	Ability Enhancement Courses (AEC) Select any 02	Skill Enhancement Electives (SEC) (Select any 08 courses, choosing at least 2 and not more than 3, from each subject, A, B, C	Discipline Specific Elective (DSE) (Select any 02 courses from each subject A, B, C	Credit hour load
1.	CC-IA CC-IB CC-IC	AEC-1		-	22
2.	CC-IIA CC-IIB CC-IIC	AEC-2		-	22
3.	CC-IIIA CC-IIIB CC-IIIC		SEC-1A SEC-2B	-	22
4.	CC-IVA CC-IVB CC-IVC		SEC-2A SEC-2C	-	22
5.	-	-	SEC-2B SEC-2C	DSE-IA DSE-IB DSE-IC	22

6.	-	-	Any 02 SEC courses from discipline A, B, C	DSE-IIA DSE-IIB DSE-IIC	22
Credits	72	8	16	36	132

d) Distribution of different types of courses with their credits for B.Sc. Chemistry (Honors)

Semester	Core Courses (CC) Note: 14 CC are available. All courses are compulsory 6 credits each	Ability Enhancement Electives (AEC) (2x4=8) Select 2 of 4 credits each	Skill Enhancement Electives (SEC) (4x2=8) Note: Select 4 of 2 credits each	Discipline Specific Elective (DSE) (4x6=24) Note: 12 DSE are available. Choose any 4 having 6 credit each	Generic Elective (GEC) (4x6=24) Note: 6 GEC are available. Choose any 4 having 6 credits each (PCM/PCB combination)		Credit hour load
1.	CC-I CC-II	AEC-1	SEC-1	-	GEC-1		24
2.	CC-III CC-IV	AEC-2	SEC-2	-	GEC-2		24
3.	CC-V CC-VI CC-VII	-	-	-	GEC-3		24
4.	CC-VIII CC-IX CC-X	-	-	-	GEC-4		24
5.	CC-XI CC-XII	-	SEC-3	DSE-1 DSE-2	-		26
6.	CC-XIII CC-XIV		SEC-4	DSE-3 DSE-4	-		26
Credits	56+28 (P)=84	08	08	16+8 (P)=24	16+8(P)=24		148

Course Structure at a Glance

7. Core Courses (CC)

Sr. No.	Name of the course	Type of course	L	T	P	Credits
CC 1.	Inorganic Chemistry-I	Core course	3	1	0	**4**
	Inorganic Chemistry Practical	Core course	0	0	2	**2**
CC 2.	Organic Chemistry-I	Core course	3	1	0	**4**
	Organic Chemistry Practical	Core course	0	0	2	**2**
CC 3.	Physical Chemistry-I	Core course	3	1	0	**4**
	Physical Chemistry Practical	Core course	0	0	2	**2**
CC 4.	Organic Chemistry-II	Core course	3	1	0	**4**
	Organic Chemistry Practical	Core course	0	0	2	**2**
CC 5.	Physical Chemistry-II	Core course	3	1	0	**4**
	Physical Chemistry Practical	Core course	0	0	2	**2**
CC 6.	Organic Chemistry-III	Core course	3	1	0	**4**
	Organic Chemistry Practical	Core course	0	0	2	**2**
CC 7.	Molecular Spectroscopy & Photochemistry	Core course	3	1	0	**4**
	Spectroscopy practicals	Core course	0	0	2	**4**
CC 8.	Physical Chemistry-III	Core course	3	1	0	**4**
	Physical Chemisry practical	Core course	0	0	2	**2**
CC 9.	Inorganic Chemistry-II	Core course	3	1	0	**4**
	Inorganic Chemistry practical	Core course	0	0	2	**2**
	Introduction to Quantum Chemistry	Core course	3	1	0	**4**

CC 10.	Chemistry Practical	Core course	0	0	2	**2**
CC 11.	Inorganic Chemistry-III	Core course	3	1	0	**4**
	Inorganic Chemistry practical	Core course	0	0	2	**2**
CC 12.	Analytical Chemistry	Core course	3	1	0	**4**
	Analytical chemistry practical	Core course	0	0	2	**2**
CC 13.	Green Chemistry	Core course	3	1	0	**4**
	Green chemistry practical	Core course	0	0	2	**2**
CC 14.	Materials Chemistry	Core course	3	1	0	**4**
	Materials Chemistry practical	Core course	0	0	2	**2**

8. Discipline Specific Elective (DSE) Course

Sr No	Name of the course	Type of course	L	T	P	Credits
1	Medicinal Chemistry	Discipline Specific Elective Course	3	1	2	**6**
2	Electrochemistry	Discipline Specific Elective course	3	1	2	**6**
3	Polymer Chemistry	Discipline Specific Elective Course	3	1	2	**6**
4	Environmental Chemistry	Discipline Specific Elective Course	3	1	2	**6**
5	Advanced Material Chemistry	Discipline Specific Elective Course	3	1	2	**6**
6	Advaned Analytical Chemistry	Discipline Specific Elective Course	3	1	2	**6**
7	Nuclear & Radiation Chemistry	Discipline Specific Elective Course	3	1	2	**6**
8	Organic spectroscopy	Discipline Specific Elective Course	3	1	2	**6**
9	Heterocyclic chemistry	Discipline Specific Elective Course	3	1	2	**6**
10	Biochemistry	Discipline Specific Elective Course	3	1	2	**6**
11	Organometallics and Bioinorganic chemistry	Discipline Specific Elective Course	3	1	2	**6**
12	Introduction to Nanochemistry & applications	Discipline Specific Elecive Course	3	1	2	**6**

9. Generic Elective Courses (GEC) (for PCM & PCB combination)

Sr. No.	Name of the course	Type of course	L	T	P	Credits
1	Mathematics-I:Mathematical methods in Chemistry	Generic Elective Courses	3	1	2	**6**
2	Life Science/Biology-I	Generic Elective Courses	3	1	2	**6**
3	Physics-I	Generic Elective Courses	3	1	2	**6**
4	Mathematics-II	Generic Elective Courses	3	1	2	**6**
5	Biology/Life Science-II	Generic Elective Courses	3	1	2	**6**
6	Physics-II	Generic Elective Courses	3	1	2	**6**

10. Ability Enhancement Courses

Sr. No.	Name of the course	Type of course	L	T/P	P	Credits
1	English for communication	Ability Enhancement Courses	3	1	0	4
2	Intellectual Property Rights	Ability Enhancement Courses	3	1	0	4
3	History of Indian Science	Ability Enhancement Courses	3	1	0	4
4	Good Laboratory Practices	Ability Enhancement Courses	3	1	0	4
5	Introduction to Forensic Science & Technology	Ability Enhancement Courses	3	1	0	4
6	Renewable Energies (Solar & Biogas)	Ability Enhancement Courses	3	1	0	4
7	Cheminformatics	Ability Enhancement Courses	3	1	0	4
8	Water remediation and conservation studies	Ability Enhancement Course	3	1	0	4
9	Research methodology	Ability Enhancement Courses	3	1	0	4
10	Chemistry in Everyday life	Ability Enhancement Courses	3	1	0	4
11	Chemistry of food, nutrtion and preservation	Ability Enhancement Courses	3	1	0	4

11. Skill Enhancement Courses

Sr. No.	Name of the course	Type of course	L/ P	T	P	Credits
1	Personality Development	Skill Enhancement Courses	2	0	0	**2**
2	Computer Applications in Chemistry	Skill Enhancement Courses	2	0	0	**2**
3	Science Communication and Popularization	Skill Enhancement Courses	2	0	0	**2**
4	Biofertilizer	Skill Enhancement Courses	2	0	0	**2**
5	Herbal Science & Technology	Skill Enhancement Courses	2	0	0	**2**
6	Fermentation Science & Technology	Skill Enhancement Courses	2	0	0	**2**
7	Environment Impact Analysis	Skill Enhancement Courses	2	0	0	**2**
8	IT Skill for Chemist	Skill Enhancement Courses	2	0	0	**2**
9	IPR and business skill for chemist	Skill Enhancement Courses	2	0	0	**2**
10	Analytical Clinical Biochemistry	Skill Enhancement Courses	2	0	0	**2**
11	Mushroom Culture Technology	Skill Enhancement Courses	2	0	0	**2**

e) Assessment Methods

Academic performance in various courses i.e. core, discipline electives, generic electives and skill enhancement courses are to be considered as parameters for assessing the achievement of students in Chemistry. A number of appropriate assessment methods of Chemistry will be used to determine the extent to which students demonstrate desired learning outcomes. Following assessment methodology should be adopted;

- The oral and written examinations (Scheduled and surprise tests),
- Closed-book and open-book tests,
- Problem-solving exercises,
- Practical assignments and laboratory reports,
- Observation of practical skills,
- Individual and group project reports,
- Efficient delivery using seminar presentations,
- *Viva voce* interviews are majorly adopted assessment methods for this curricullum.
- The computerized adaptive testing, literature surveys and evaluations, peers and self-assessment, outputs form individual and collaborative work are also other important approaches for assessment purposes.

A continuous assessment method throughout the programme shall inculcate regular reading habit in the students' and continuous observation about weaker aspect of the students'.

f) Suggested List of Seminar Topics (not limited to)

1. Carbon dating
2. Carbohydrate chemistry
3. Aliphatic Compounds
4. Biodiversity and climate change
5. Current Developments in Analytical Techniques
6. Boron Chemistry
7. Role of DNA sequencing in chemical analysis.
8. Catalytic converter
9. Chemistry of diamonds
10. DNA markers and Genetic diversity
11. Biomaterials
12. Polymers in drug delivery system
13. Hydrogels in medical applications
14. Adsorption techniques in industry
15. Chiral molecules
16. Water conservation
17. Rewable energy for sustainable developments
18. Fluroide in water.
19. Arsenic and its remediation.
20. Paint chemistry
21. Exotic molecules
22. Hybridization
23. Fuel chemistry
24. Nanomedicine
25. Advances in Supramolecular Chemistry
26. Functional materials
27. Quazi crystals

g) Suggested List of Topics for Group Discussion (not limited to)

1. Smart materials
2. Solid oxide fuels
3. Desalination technology
4. Surfactants, colloids and its applications in industry.
5. Water based polymers
6. Molecular spectroscopy and is application.
7. Explosive chemistry
8. CO_2 capture
9. Green house effects.
10. Chemistry and Biotechnology; Past present and Future
11. Mesoporous materials
12. CNT and its applications in future
13. Fullerene
14. Recent advances in atomic layer deposition
15. Thermoelectric materials
16. Origin of seeds
17. Chemistry of separation of small and complex molecules
18. Environmental Nanotoxicology
19. Bioconjugate chemistry
20. Intelligent molecules in biomedical applications
21. Chemical neuroscience
22. Atmospheric physical chemistry
23. Organic electronics
24. Climate change- a solution through application of Chemistry
25. Stratospheric Ozone depletion and marine productivity – a chemistry solution.
26. Good ozone vs. bad ozone
27. Air pollution and climate change
28. Biodiversity under climate changing scenarios
29. Inorganic reaction mechanism
30. Solution Chemistry

31. Biomolecular chemistry
32. Boron chemistry and its application in medical science and technology
33. Chemistry of wine and coffee.
34. Graphene – recent advancement.
35. Hydrogen storage.
36. Food chemistry

h) Suggested Topics for Individual/ Team Projects (not limited to)

1. Synthesis of Aspirin.
2. Finding EMF of electrochemical cells.
3. Prepration of biodiesel.
4. Study of chemistry of photography.
5. Water analysis of nearby areas; finding out the toxic/heavy metals, anions and purification of water using simple available lab technology.
6. Study of air-pollution parameters of a given locality.
7. Forensic analysis of given species.

CORE COURSES

These are 12 courses. All courses are compulsory. These courses have the following credit pattern.

For Theory papers:

L	T	P	Cr
3	1	0	4

For Practical based papers:

L	T	P	Cr
0	0	2	2

1.Inorganic Chemistry-I:

L	T	P	Cr
3	1	0	4

On completion of this course, the students will be able to understand:

Learning objective:

1. Atomic theory and its evolution.
2. Learning scientific theory of atoms, concept of wave function.
3. Elements in periodic table; physical and chemical characteristics, periodicity.
4. To predict the atomic structure, chemical bonding, and molecular geometry based on accepted models.
5. To understand atomic theory of matter, composition of atom.
6. Identity of given element, relative size, charges of proton, neutron and electrons, and their assembly to form different atoms.
7. Defining isotopes, isobar and isotone.
8. Physical and chemical characteristics of elements in various groups and periods according to ionic size, charge, etc. and position in periodic table.
9. Characterize bonding between atoms, molecules, interaction and energetics (ii) hybridization and shapes of atomic, molecular orbitals, bond parameters, bond- distances and energies.
10. Valence bond theory incorporating concepts of hybridization predicting geometry of molecules.

11. Importance of hydrogen bonding, metallic bonding.

Self-study:

1. Electronic configuration of various elements in periodic table
2. Predicting structure of molecules
3. How hydrogen bonding, metallic bonding is important in common materials' scientific applications to material fabrication

Atomic Structure: (10 classes of 60 minutes each)

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de' Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ2. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of *s*, *p*, *d* and *f* orbitals. Contour boundary and probability diagrams. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.

Periodicity of Elements: (10 classes of 60 minutes each)

s, *p*, *d*, *f* block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to *s* and *p*-block.

(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.

(b) Atomic radii (van'der Waals)

(c) Ionic and crystal radii.

(d) Covalent radii (octahedral and tetrahedral)

(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.

(f) Electron gain enthalpy, trends of electron gain enthalpy.

(g)Electronegativity, Pauling, Mullikan, Allred Rachow scales, electronegativity and bond order, partial charge, hybridization, group electronegativity. Sanderson electron density ratio.

Chemical Bonding: (14 classes of 60 minutes each)

(i) *Ionic bond:* General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation, expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy.

(ii) *Covalent bond:* Lewis structure, Valence Shell Electron Pair Repulsion Theory (VSEPR), Shapes of simple molecules and ions containing lone-and bond-pairs of electrons multiple bonding, sigma and pi-bond approach, Valence Bond theory, (Heitler-London approach). Hybridization containing s, p and s, p, d atomic orbitals, shapes of hybrid orbitals, Bents rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of simple homonuclear and heteronuclear diatomic molecules, MO diagrams of simple tri and tetra-atomic molecules, e.g., N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2, HCHO, (idea of s-p mixing and orbital interaction to be given). Covalent character in ionic compounds, polarizing power and polarizability. Fajan rules, polarization. Ionic character in covalent compounds: Bond moment and dipole moment. ionic character from dipole moment and electronegativities.

Metallic bonding and Weak chemical forces: (6 classes of 60 minutes each)

(iii) *Metallic Bond:* Qualitative idea of free electron model, Semiconductors, Insulators.

(iv) *Weak Chemical Forces:* van'der Waals, ion-dipole, dipole-dipole, induced dipole dipole-induced dipole interactions, Lenard-Jones 6-12 formula, hydrogen bond, effects of hydrogen bonding on melting and boiling points, solubility, dissolution.

Recommended Books/References:

1.Lee, J. D. *Concise Inorganic Chemistry,* Wiley, 5th Ed^{n}.

2.Douglas, B.E., McDaniel, D.H., Alexander J.J., *Concepts & Models of Inorganic Chemistry, (Third Edition)* John Wiley & Sons,1999.

3.Atkins, P. W. and DePaula, J. *Physical Chemistry*, Tenth Edition, Oxford University Press, 2014.

4. Rodger, G. E. *Inorganic and Solid State Chemistry*, Cengage Learning, 2002.

1.1. Inorganic Chemistry Practical

L	T	P	Cr
0	0	2	2

(A) Titrimetric Analysis

(i) Calibration and use of apparatus.

(ii) Preparation of solutions of different Molarity/Normality of titrants.

(iii) Use of primary and secondary standard solutions.

(B) Acid-Base Titrations

(i) Estimation of carbonate and hydroxide present together in mixture.

(ii) Estimation of carbonate and bicarbonate present together in a mixture.

(iii) Estimation of free alkali present in different soaps/detergents

(C) Oxidation-Reduction Titrimetry

(i) Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution.

(ii) Estimation of oxalic acid and sodium oxalate in a given mixture.

(iii) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal (diphenylamine, anthranilic acid) and external indicator.

Recommended Books/References:

1. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis* Sixth Edition, Pearson, 2009.
2. Svehala G. and Sivasankar I. B, Vogel's Qualitative Inorganic Analysis, Pearson, India, 2012.

2.Core course: Organic Chemistry-I

L	T	P	Cr
3	1	0	4

On completion of this course, the students will be able to understand:

Learning objectives:

1. Basic of organic molecules, structure, bonding, reactivity and reaction mechanisms.
2. Stereochemistry of organic molecules – conformation and configuration, asymmetric molecules and nomenclature.
3. Aromatic compounds and aromaticity, mechanism of aromatic reactions.
4. Understanding hybridization and geometry of atoms, 3-D structure of organic molecules, identifying chiral centers.
5. Reactivity, stability of organic molecules, structure, stereochemistry.
6. Electrophile, nucleophiles, free radicals, electronegativity, resonance, and intermediates along the reaction pathways.
7. Mechanism of organic reactions (effect of nucleophile/leaving group, solvent), substitution *vs*. elimination.

Self-study:

1. Design and syntheses of organic molecules.
2. Structure identification through IR, NMR and Mass spectroscopic data.
3. Lab/Instrumentation techniques used for analyzing reaction mechanisms.
4. Advanced soft-wares/Models used for predicting stereochemistry/study of energy minimization of organic molecules.

Basics of Organic Chemistry: (10 classes of 60 minutes each)

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties. Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength. Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophlicity and basicity; Types, shape and relative stabilities of reaction intermediates (Carbocations, Carbanions, Free radicals and Carbenes).

Organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

Stereochemistry: (6 classes of 60 minutes duration each)

Concept of asymmetry, Fischer Projection, Newmann and Sawhorse projection formulae and their interconversions; Geometrical isomerism: cis–trans and, syn-anti isomerism E/Z notations with C.I.P rules. Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, meso structures, Racemic mixtures, Relative and absolute configuration: D/L and R/S designations.

Chemistry of Aliphatic Hydrocarbons: (18 classes of 60 minutes duration each)

A. Carbon-Carbon sigma bonds

Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz- Fittig Reactions, Free radical substitutions: Halogenation - relative reactivity and selectivity.

B. Carbon-Carbon pi-bonds

Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations. Reactions of alkenes: Electrophilic additions their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroboration- oxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation (oxidation). 1, 2- and 1, 4- addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethyl benzene. Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions.

C. Cycloalkanes and Conformational Analysis

Cycloalkanes and stability, Baeyer strain theory, Conformation analysis, Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms.

Aromatic Hydrocarbons (6 classes of 60 minutes duration each)

Aromaticity: Huckel’s rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of substituent groups.

Recommended Books/References:

1. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, 6th Edn., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Pine S. H. Organic Chemistry, Fifth Edition, McGraw Hill, (2007)
3. F. A. Carey, Organic Chemistry, Seventh Edition, Tata McGraw Hill (2008).
4. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed., (2012), Oxford Universitiy Press.
5. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry, Part A: Structure and mechanism, Kluwer Academic Publisher, (2000).

2.1.Course course: Organic Chemistry Practical

L	T	P	Cr
0	0	2	2

1. Checking the calibration of the thermometer.

2. Purification of organic compounds by crystallization using the following solvents:

a. Water b. Alcohol c. Alcohol-Water

3. Determination of the melting points of given organic compounds and unknown organic compounds (using Kjeldahl method and electrically heated melting point apparatus).

4. Effect of impurities on the melting point – mixed melting point of two unknown organic compounds.

5. Determination of boiling point of liquid compounds. (boiling point lower than and more than 100 °C by distillation and capillary method)

5.Chromatography

a. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography

b. Separation of a mixture of two sugars by ascending paper chromatography

c. Separation of a mixture of *o*-and *p*-nitrophenol or o-and p-aminophenol by thin layer chromatography (TLC).

Recommended Books/Reference:

1.Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)

2.Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.*, Pearson (2012)

3.Core course: Physical Chemistry-I

L	T	P	Cr
3	1	0	4

On completion of this course, the students will be able to understand:

Learning objective:

1. Familiarization with various states of matter.
2. Physical properties of each state of matter and laws related to describe the states.
3. Calculation of lattice parameters.
4. Electrolytes and electrolytic dissociation, salt hydrolysis and acid-base equilibria.
5. Understanding Kinetic model of gas and its properties.
6. Maxwell distribution, mean-free path, kinetic energies.
7. Behavior of real gases, its deviation from ideal behavior, equation of state, isotherm, and law of corresponding states.
8. Liquid state and its physical properties related to temperature and pressure variation.
9. Properties of liquid as solvent for various household and commercial use.
10. Solids, lattice parameters – its calculation, application of symmetry, solid characteristics of simple salts.
11. Ionic equilibria – electrolyte, ionization, dissociation.
12. Salt hydrolysis (acid-base hydrolysis) and its application in chemistry.

Self-study:

1. Determination of lattice parameters of given salt.
2. Study of X-Ray diffraction pattern and finding out reference from JCPDI file.
3. Numerical related to salt hydrolysis, ionic equilibria.

Gaseous state: (**12 classes of 60 minutes duration each**)

Behavior of real gases: Deviations from ideal gas behavior, compressibility factor, and its variation with pressure for different gases. Causes of deviation from ideal behavior. van der Waals equation of state, its derivation and application in explaining real gas behaviour; van der Waals equation expressed in virial form, Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, critical and van der Waals constants, law of corresponding states.

Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Liquid state: (5 classes of 60 minutes duration each)

Structure and physical properties of liquids; vapour pressure, surface tension, viscosity, and their dependence on temperature, Effect of addition of various solutes on surface tension, cleansing action of detergents. Structure of water.

Ionic equilibria: (13 classes of 60 minutes duration each)

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constants of mono-, di- and tri-protic acids.

Salt hydrolysis, hydrolysis constants, degree of hydrolysis and pH for different salts. Buffer solutions; Henderson equation, buffer capacity, buffer range, buffer action, applications of buffers in analytical chemistry, Solubility and solubility product.

Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB) Application of HSAB principle.

Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of indicators; selection of indicators and their limitations. Multistage equilibria in polyelectrolytes.

Solid state: (10 classes of 60 minutes duration each)

Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl. Various types of defects in crystals, Glasses and liquid crystals.

Recommended Text books/references:

1. Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 8th Ed., Oxford University Press (2006).
2. Ball, D. W. *Physical Chemistry* Thomson Press, India (2007).
3. Castellan, G. W. *Physical Chemistry* 4th Ed. Narosa (2004).
4. Mortimer, R. G. *Physical Chemistry* 3rd Ed. Elsevier: NOIDA, UP (2009).
5 G. M. Barrow, Tata McGraw Hill (Fifth Edition) (2007)

3.1.Physical chemistry Practical

L	T	P	Cr
0	0	2	2

1. Surface tension measurements.

a. Determine the surface tension by (i) drop number (ii) drop weight method.

b. Study the variation of surface tension of detergent solutions with concentration.

2. **Viscosity measurements using Ostwald's viscometer**.

a. Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.

b. Viscosity of sucrose solution with the concentration of solute.

3. pH metry

a. Effect on pH of addition of HCl/NaOH to solutions of acetic acid,
sodium acetate and their mixtures.

b. Preparation of buffer solutions of different pH

i. Sodium acetate-acetic acid

ii. Ammonium chloride-ammonium hydroxide

c. pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.

d. Determination of dissociation constant of a weak acid.

Recommended text books/references:

1.Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).

2.Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed*.; McGraw-Hill: New York (2003).

3 Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.;* W.H. Freeman & Co.: New York (2003).

4 Athawale V. D. amd Mathur P. Experimental Physical Chemistry,, New Age Intenational (2001)

4.Core course: Organic Chemistry-II

L	T	P	Cr
3	1	0	4

After completion of the course, the learner shall be able to understand:
Learning objective:

1. Familiarization about classes of organic compounds and their methods of preparation.
2. Basic uses of reaction mechanisms.
3. Name reactions, uses of various reagents and the mechanism of their action.
4. Preparation and uses of various classes of organic compounds.
5. Organometallic compounds and their uses.
6. Organic chemistry reactions and reaction mechanisms.
7. Use of reagents in various organic transformation reactions.

Self-study:

1. Elucidating reaction mechanisms for organic reactions.
2. Organometallic compounds and their uses.
3. Use of active methylene groups in organic mechanism and preparation of new organic compounds.

Chemistry of Halogenated Hydrocarbons: (8 classes of 60 minutes duration each)

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_N^i mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.

Aryl halides: Preparation, including preparation from diazonium salts. nucleophilic aromatic substitution; SNAr, Benzyne mechanism.

Relative reactivity of alkyl, allyl/benzyl, vinyl and aryl halides towards nucleophilic substitution reactions.

Organometallic compounds of Mg and Li and their use in synthesis.

Alcohols, Phenols, Ethers and Epoxides: (6 classes of 60 minutes duration each)

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement.

Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism.

Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$

Carbonyl Compounds: (10 classes of 60 minutes duration each)

Structure, reactivity and preparation; Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α-substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV, PDC and PGC);

Addition reactions of unsaturated carbonyl compounds: Michael addition.

Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.

Carboxylic Acids and their Derivatives: (10 classes of 60 minutes duration each)

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids; Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmannbromamide degradation and Curtius rearrangement.

Sulphur containing compounds: (6 classes of 60 minutes duration each)

Preparation and reactions of thiols, thioethers and sulphonic acids.

Recommended Books/references:

1 Solomons, T.W G., Fryhle, B. Craig. *Organic Chemistry,* John Wiley & Sons, Inc (2009).

2 McMurry, J.E. *Fundamentals of Organic Chemistry*, Seventh edition Cengage Learning, 2013.

3 P Sykes, *A Guide Book to Mechanism in Organic Chemistry*, 6th Edition (1997), Orient Longman, New Delhi.

4 Morrison R. T. and Boyd R. N. Organic Chemistry, Sixth Edition Prentice Hall India, 2003.

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4.1.Core course: Organic Chemistry-Practical

L	T	P	Cr
0	0	2	2

(List of experiments given are suggestive. One experiment from each group to be demonstrated)

1.Identification of elements (N, S, and halogen) and Functional group tests for alcohols, phenols, carbonyl, carboxylic acid and amine group of compounds.

2. Organic preparations:

i. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*-toluidines and *o*-, *m*-, *p*-anisidine) and phenols (β-naphthol, vanillin, salicylic acid) by any one method: (Using conventional method.and Using green chemistry approach)

ii. Benzolyation of one of the amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and one of the phenols (*β*-naphthol, resorcinol, *p*-cresol) by Schotten-Baumann reaction.

iii. Oxidation of ethanol/ isopropanol (Iodoform reaction).

iv. Bromination (any one)

a. Acetanilide by conventional methods

b. Acetanilide using green approach (Bromate-bromide method)

v. Nitration: (any one)

a. Acetanilide/nitrobenzene by conventional method

b. Salicylic acid by green approach (using ceric ammonium nitrate).

vi. Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.

vii. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.

viii. Hydrolysis of amides and esters.

ix. Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.

x. *S*-Benzylisothiouronium salt of one each of water soluble/ insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).

xi. Aldol condensation with either conventional or green method.

xii. Benzil-Benzilic acid rearrangement.

Collected solid samples may be used for recrystallization, melting point and TLC.

Recommended Books/References:

1 Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)

2 Furniss, B.S., Hannaford, A.J., Smith, P.W.G. & Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.* Pearson (2012)

3 Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000)

4 Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000).

5.Core course: Physical Chemistry-II

L	T	P	Cr
3	1	0	4

After completion of the course, the learner shall be able to understand:

Learning objective:

1. Laws of thermodynamics and concepts.
2. Partial molar quantities and its attributes.
3. Dilute solution and its properties.
4. Understanding the concept of system, variables, heat, work, and laws of thermodynamics.
5. Understanding the concept of heat of reactions and use of equations in calculations of bond energy, enthalpy, etc.
6. Understanding the concept of entropy; reversible, irreversible processes. Calculation of entropy using 3nd law of thermodynamics.
7. Understanding the application of thermodynamics: Joule Thompson effects, partial molar quantities.
8. Understanding theories/thermodynamics of dilute solutions.

Self-study:

1. Use of thermochemical equations for calculation of energy and related terms.
2. Use of thermodynamics in explaining chemical behavior of solute/solvent and reactions.
3. Study of calorimeter principle and its use.

Introduction to thermodynamics: (6 classes of 60 minute duration each)

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics. *First law:* Concept of heat, q, work, w, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions.

Thermochemistry: (6 classes of 60 minutes duration each)

Heats of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, effect of temperature (Kirchhoff's equations), pressure on enthalpy of reactions.

Second Law: (6 classes of 60 minutes duration each)

Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes.

Third law of thermodynamics: (4 classes of 60 minutes duration each)

Third Law of thermodynamics, residual entropy, calculation of absolute entropy of molecules.

Free Energy Functions: (6 classes of 60 minutes duration each)

Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

Partial molar quantities: (6 classes of 60 minutes duration each)

Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs-Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

Dilute solutions: (6 classes of 60 minutes duration each)

Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Excess thermodynamic functions. Thermodynamic derivation using chemical potential to derive relations between the four colligative properties: [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

Recommended Books/References

1 Atkins P. and De Paula, J. *Physical Chemistry* Tenth Ed., OUP, 2014.

2 Castellan, G. W. *Physical Chemistry 4th Ed.*, Narosa, 2004.

3 Engel, T. and Reid, P. *Physical Chemistry 3rd Ed.*, Prentice Hall, 2012.

4 McQuarrie, D. A. and Simon, J. D. *Molecular Thermodynamics* Viva Books, 2004.

5 Roy, B. N. Fundamentals of Classical and Statistical Thermodynamics Wiley, 2001

6 Commonly Asked Questions in Thermodynamics. CRC Press, 2011.

7 Levine, I .N. *Physical Chemistry* 6th Ed., Tata Mc Graw Hill, 2010.

8 Metz, C.R. *2000 solved problems in chemistry*, Schaum Series, 2006.

5.1.Core course: Physical Chemistry-Practical

L	T	P	Cr
0	0	2	2

(A list of suggested experiments are given. However, more experiments can be added based on facilities available in the laboratories).

1. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.

2. Study the equilibrium of at least one of the following reactions by the distribution method:

(i) I_2 (aq) + I^- ---→ I_3^-(aq)

(ii) Cu^{2+}(aq) + $n NH_3 \rightarrow Cu(NH_3)_n$

3. Study the kinetics of the following reactions.

a. Acid hydrolysis of methyl acetate with hydrochloric acid.

b. Saponification of ethyl acetate.

Adsorption

Verification of Freundlich and Langmuir isotherms for adsorption of acetic acid and selected organic dye(s) on activated charcoal.

(Use of calorimeter for calculation of heat of reactions may be demonstrated)

Recommended Books/References:

1.Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand, New Delhi, 2011.

2.Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry*, Eighth Edition, McGraw-Hill(2003).

3 Halpern, A. M. and McBane, G. C. *Experimental Physical Chemistry*, Third Edition, W, H. Freeman (2003).

6.Core course: Organic Chemistry-III

L	T	P	Cr
3	1	0	4

After completion of the course, the learner shall be able to understand:

Learning objective:

1. Nitrogen containing functional groups and their reactions.
2. Familiarization with polynuclear hydrocarbons and their reactions.
3. Heterocyclic compounds and their reactions.
4. Alkaloids and Terpenes
5. Understanding reactions and reaction mechanism of nitrogen containing functional groups.
6. Understanding the reactions and mechanisms of diazonium compounds.
7. Understanding the structure and their mechanism of reactions of selected polynuclear hydrocarbons.
8. Understanding the structure, mechanism of reactions of selected heterocyclic compounds.
9. Classification, structure, mechanism of reactions of few selected alkaloids and terpenes.

Self-study:

1. Use of benzene diazonium salt in organic synthesis.
2. Applications of heterocyclic compounds in pharmaceutics/drugs and the mechanism of actions.
3. Pharmaceutics/Biomedical applications of alkaloids and terpenes.
4. Nitrogen containing organic compounds/heterocyclic compounds in synthetic chemistry.

Nitrogen Containing Functional Groups (8 classes of 60 minutes duration each).

Preparation and important reactions of nitro and compounds, nitriles and isonitriles Amines: Effect of substituent and solvent on basicity; Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann's exhaustive methylation, Hofmann-elimination reaction; Distinction between 1°, 2° and 3° amines with Hinsberg reagent and nitrous acid. Diazonium salts: Preparation and synthetic applications.

Polynuclear Hydrocarbons: (8 classes of 60 minutes duration each)

Reactions of naphthalene phenanthrene and anthracene Structure, Preparation and structure elucidation and important derivatives of naphthalene and anthracene; Polynuclear hydrocarbons.

Heterocyclic Compounds: (12 classes of 60 minutes duration each)

Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom; Synthesis, reactions and mechanism of substitution reactions of Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Pyrimidine, Structure elucidation of indole, Fischer indole synthesis and Madelung synthesis), Structure elucidation of quinoline and isoquinoline, Skraup synthesis, Friedlander's synthesis, Knorr quinoline synthesis, Doebner-Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction Derivatives of furan: Furfural and furoic acid.

Alkaloids (6 classes of 60 minutes duration each)

Natural occurrence, General structural features, Isolation and their physiological action Hoffmann's exhaustive methylation, Emde's modification, Structure elucidation and synthesis of Hygrine and Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine.

Terpenes (6 classes of 60 minutes duration each)

Occurrence, classification, isoprene rule; Elucidation of stucture and synthesis of Citral, Neral and α-terpineol.

Recommended Text Books/references:

1.Morrison, R. T., Boyd, R. N., Bhatterjee, S.K., Organic Chemistry, 7th Edn., Pearson.

2 Acheson, R.M. *Introduction to the Chemistry of Heterocyclic compounds,* John Welly & Sons (1976).

3 Solomons, T.W., Fryhle Craig, *Organic Chemistry,* John Wiley & Sons, Inc (2009).

4 McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.

5 Kalsi, P. S. *Organic reacations and their mechanisms*, New Age Science (2010).

6 Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry,* Oxford University Press Inc., New York (2001).

7 Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, Prajati Parakashan (2010).

8 Bansal R. K. *Heterocyclic Chemistry: Syntheses, Reactions and Mechanisms*, New Age, Third Edition (1999).

9.Clayden J., Greeves N., Warren S., Organic Chemistry, (2nd Ed)., (2012), Oxford University Press.

6.1.Core course: Organic Chemistry Practical

L	T	P	Cr
0	0	2	2

1. Qualitative analysis of unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups, for e.g. salicylic acid, cinnamic acid, nitrophenols, etc.
2. Identification of functional groups of simple organic compounds by IR spectroscopy and NMR spectroscopy (IR and NMR of simple organic compounds may be done wherever facilities are available, otherwise sample spectra may be provided for simple organic compounds like Ethanol, Aniline, Phenol, acetic acid, other simple aldehydes, carboxylic acid, etc., for identification of functional groups. References from standard spectroscopy books may also be taken for such purpose for enhancing students understanding and skill).
3. Preparation of methyl orange.
4. Extraction of caffeine from tea leaves.
5. Analysis of Carbohydrate: aldoses and ketoses, reducing and non-reducing sugars using simple lab procedures.

Recommended Books/References:

1.Vogel, A.I. *Quantitative Organic Analysis*, Part 3, Pearson (2012).
2. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)
3. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012)
4. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000).
5. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000).

7. Core course: Molecular Spectroscopy & Photochemistry

L	T	P	Cr
3	1	0	4

Unit-I: (15 classes of 60 minutes duration each)

Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation. Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies. Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches.

Unit-II: (10 classes of 60 minutes duration each)

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.

Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation.

Unit-III: (15 classes of 60 minutes duration each)

Photophysical and photochemical processes: laws of photochemistry, quantum yield. Jablonski diagrams: Franck-Condon principle, Law of photochemical equivalence, quantum efficiency, low and high quantum efficiency. kinetics of photochemical reactions ($H_2 + Br_2 = HBr$, $2HI = H_2 + I_2$), energy transfer in photochemical reactions (photosensitization and quenching), fluorescence, phosphorescence, chemiluminescence, Discussion of Electronic spectra and photochemistry (Lambert-Beer law and its applications).

Recommended books/References:

1. Laideler K. J. and Meiser J. M. *Physical Chemistry* Third Edition (International)1999

2. Levine I. N., *Physical Chemistry,* Fourth Edition), McGraw-Hill (International), 1995.

3. McQuarrie D. A. and Simon J. D. *Physical Chemistry- A Molecular Approach,* University Science Books, 1998

4. Rohatgi-Mukherjee K. K. Fundamentals of Photochemistry, New age (revised second edition).

5. Banwell, C. N. & McCash, E. M. *Fundamentals of Molecular Spectroscopy* 4th Ed. Tata McGraw-Hill: New Delhi (2006).

7.1.Suggested laboratory experiments:

L	T	P	Cr
0	0	2	2

(i). Determination of indicator constant - colorimetry. (instructor may vary indicators available in the lab).

(ii). Verification of Beer's Law - Determination of concentration of solution by colorimetry.

(Instructor may explain the principle of using colorimeter, its handling drawing standard calibration curve, and its application in finding unknown concentration of dyes, concentration of metal solutions (*e.g.*Ni, Cu using appropriate reagent) from standard calibration curve.

Suggested books/reference books:

1. Practicals in physical chemistry – a modern approach, P.S.Sindhu, Macmillan,

2. Experiments in Physical Chemistry, J.M.Wilson, R.J.Newcomb, A.R.Denaro, 2nd Edn., Elsevier.

8. Core course: Physical Chemistry-III

L	T	P	Cr
3	1	0	4

After completion the course, the learner shall be able to understand:

Learning objective:

1. Phases, components, Gibbs phase rule, Phase diagrams and applications.
2. Chemical kinetics: type of reactions, determination of rate, theories of reaction rate, steady state approximation.
3. Catalyst – mechanism, acid base catalysis, enzyme catalysis.
4. Adsorption isotherms.
5. Understanding phases, components, Gibb's phase rule and its applications, construction of phase diagram of different systems, the application of phase diagram.
6. Understanding the basics of chemical kinetics: determination of order, molecularity, and understanding theories of reaction rates, determination of rate of opposing/parallel/chain reactions with suitable examples, application of steady state kinetics, Steady-state approximation.
7. Catalyst – mechanism of catalytic action, enzyme catalysis.
8. Langmuir, Freundlich – adsorption isotherms, significance, multilayer adsorption – theory and significance.

Self-study:

1. Application of phase diagram.
2. Study of reaction kinetics, Fast reactions.
3. Heterogeneous catalysis used in industry and its mechanism of action.
4. Application of adsorption isotherms in metal adsorption, significance.

Phase Equilibria: (10 classes of 60 minutes duration each)

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems, with applications. Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions. Three component systems, water-chloroform-acetic acid system, triangular plots. *Binary solutions:* Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and nonideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation. Nernst distribution law: its derivation and applications.

Chemical Kinetics: (10 classes of 60 minutes duration each)

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated rate laws for first, second and fractional order reactions, pseudounimolecular reactions, determination of the order, kinetics of complex reactions (limited to first order): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms) (iv) chain reactions. Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates.

Catalysis: (10 classes of 60 minute duration each)

Types of catalyst, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces; effect of particle size and efficiency of nanoparticles as catalysts. Enzyme catalysis, Michaelis-Menten mechanism, acid-base catalysis.

Surface chemistry: (10 classes of 60 minutes duration each)

Physical adsorption, chemisorption, adsorption isotherms (Freundlich, Temkin, Derivation of Langumuir adsorption isotherms, surface area determination), BET theory of multilayer adsorption (no derivation), Adsorption in solution.

Recommended books/References:

1. Atkins P. W. and De Paula J., *Physical Chemistry, (*tenth edition) Oxford University Press, 2014.

2 Castellan, G. W. *Physical Chemistry*, 4th Ed., Narosa , 2004.

3 McQuarrie, D. A. & Simon, J. D., *Molecular Thermodynamics*, Viva Books, 2004.

4 Engel, T. & Reid, P. *Physical Chemistry* Third Edition, Prentice-Hall,2012.

5 Zundhal, S.S. *Chemistry concepts and applications* Cengage India, 2011
6 Ball, D. W. *Physical Chemistry* Cengage India, 2012.
7 Mortimer, R. G. *Physical Chemistry 3rd Ed.*, Elsevier: NOIDA, UP, 2009.
8.Levine, I. N. *Physical Chemistry 6th Ed.*, Tata McGraw-Hill, 2011.
9.Metz, C. R. *Physical Chemistry 2nd Ed.*, Tata McGraw-Hill, 2009.

8.1.Core course: Physical Chemistry Practical

L	T	P	Cr
0	0	2	2

Conductometry

1 Determination of cell constant

2 Equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

3.Conductometric titrations of: Strong acid Vs. strong base (ii) Weak acid vs. strong base, (iii) Mixture of strong acid and (iv)weak acid vs. strong base, Strong acid vs. weak base.

Potentiometry

Potentiometric titrations of: (i) Strong acid vs. strong base (ii) Weak acid vs. strong base
(iii) Dibasic acid vs. strong base (iv) Potassium dichromate vs. Mohr's salt.

Recommend books/References:

1 Khosla, B. D.; Garg, V. C. and Gulati, A. *Senior Practical Physical Chemistry*, R. Chand New Delhi, 2011.
2 Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry* Eighth Edition; McGraw-Hill: New York, 2003.
3 Halpern, A. M. and McBane, G. C. *Experimental Physical Chemistry 3rd Ed.;* W.H. Freeman & Co.: New York, 2003.

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

9. Core course : Inorganic Chemistry-II

L	T	P	Cr
3	1	0	4

After completion of the course, the learner shall be able to understand:

Learning objective:

1. Oxidation-Reductions and their use in metallurgy.
2. Chemistry of s and p-block elements.
3. Chemistry of noble gases.
4. Inorganic polymers and their use.
5. Understanding redox reactions in hydrometallurgy processes.
6. Structure, bonding of s and p block materials and their oxides/compounds.
7. Understanding chemistry of boron compounds and their structures.
8. Chemistry of noble gases and their compounds; application of VSEPR theory in explaining structure and bonding.
9. Understanding chemistry of inorganic polymers, their structures and uses.

Self-study:

1. Extraction of metals through metallurgical operations and their uses.
2. Bonding of various s and p block elements.
3. Use of boron compounds.
4. Chemistry of inorganic polymers and their uses.

Oxidation-Reduction and general principle of metallurgy: (8 classes of 60 minutes duration each)

Redox equations, Standard Electrode Potential and its application to inorganic reactions. Occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon or carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel- de Boer process and Mond's process, Zone refining.

Chemistry of *s* and *p* Block Elements: (16 classes of 60 minutes duration each)

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behavior of first member of each group. Allotropy and catenation. Complex formation tendency of *s* and *p* block elements. Hydrides and their classification ionic, covalent and interstitial. Basic beryllium acetate and nitrate.

Structure, bonding, preparation, properties and uses. Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Per-oxo acids of Sulphur inter-halogen compounds, poly-halide ions, pseudo-halogens, properties of halogens.

Noble Gases: (8 classes of 60 minutes duration each)

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Bonding in noble gas compounds (Valence bond and MO treatment for XeF_2), Shapes of noble gas compounds (VSEPR theory).

Inorganic Polymers: (8 classes of 60 minutes duration each)

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes, and polysulphates.

Recommended books/references:

1 Lee, J.D. *Concise Inorganic Chemistry*, ELBS, 1991.

2 Douglas, B.E; Mc Daniel, D.H. & Alexander, J.J. *Concepts & Models of Inorganic Chemistry 3rd Ed.*, John Wiley Sons, N.Y. 1994.

3 Greenwood, N.N., Earnshaw. *Chemistry of the Elements*, Butterworth-Heinemann. 1997.

4 Cotton, F.A. & Wilkinson, G. *Advanced Inorganic Chemistry*, Wiley, VCH, 1999.

5 Rodger, G.E. *Inorganic and Solid State Chemistry*, Cengage Learning India Edition, 2002.

6 Miessler, G. L. & Donald, A. Tarr. *Inorganic Chemistry* Fourth Ed., Pearson, 2010

7 Atkins, P. W and Shriver D. N. *Atkins' Inorganic Chemistry* 5th Ed. Oxford University Press (2010).

9.1.Course course: Inorganic Chemistry-practical

L	T	P	Cr
0	0	2	2

(A) Iodo / Iodimetric Titrations

(i) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution (Iodimetrically).

(ii) Estimation of (i) arsenite and (ii) antimony iodimetrically

(iii) Estimation of available chlorine in bleaching powder iodometrically.

(B) Inorganic preparations

(i) Cuprous Chloride, Cu_2Cl_2

(ii) Preparation of Aluminium potassium sulphate (Potash alum) or Chrome alum.

Recommended books/references:

Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis* Sixth Edition Pearson, 2009.

(The above list of experiments are suggestive. Faculty/academic bodies may incorporate revision/may incorporate text and reference books as per need).

10. Introduction to Quantum Chemistry:

L	T	P	Cr
3	1	0	4

Unit-I: Introduction to black-body radiation and distribution of energy, photo-electic effect, concept of quantization, wave particle duality (de-Broglie's hypothesis), The uncertainty principle, The wave function: wave function and its interpretation, conditions of normalization and Orthogonality and its significance. Basic idea about operators, eigen function and values, Schrodinger equation and application to free-particle and particle in a box, boundary conditions, wave functions and energies, degeneracy, hydrogen atom, Schrodinger equation in polar coordinates, radial and angular parts of the hydrogenic orbitals, degeneracies, spherical harmonics, representations of hydrogenic orbitals. (**15 classes of 60 minutes durations**)

Unit-II: Quantitative treatment of simple harmonic osciallator model, setting up of Schodinger equation and discussion of solution of wave functions. Rigid rotator model and discussion of application of Schrodinger equation. idea about transformation to spherical polar coordinate, discussion on solution, (**15 classes of 60 minutes durations**)

Unit-III: (**10 classes of 60 minutes durations**)

Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus. Valence bond and molecular orbital approaches, LCAO-MO treatment of H_2, H_2^+; bonding and anti-bonding orbitals, Comparison of LCAO-MO and VB treatments of H_2 (only wavefunctions, detailed solution not required) and their limitations.

Recommended books/References:

1. Laideler K. J. and Meiser J. M. *Physical Chemistry* Third Edition (International)1999

2. Levine I. N., *Physical Chemistry,* Fourth Edition), McGraw-Hill (International), 1995.

3. McQuarrie D. A. and Simon J. D. *Physical Chemistry- A Molecular Approach,* University

Science Books, 1998.

4.Chandra, A. K. *Introductory Quantum Chemistry* Tata McGraw-Hill (2001).

5. House, J. E. *Fundamentals of Quantum Chemistry* 2nd Ed. Elsevier: USA (2004).

10.1.Suggested laboratory experiments:

L	T	P	Cr
0	0	2	2

(i)The students may be demonstrated hyperchem lab activities – building a molecular model (leveling of atoms, editing individual atoms, changing bond order, centrering, rotation of atoms), Selection of calculation method (*e.g.*force field calculation, ab-initio set up), displaying calculated properties, (instructor may demonstrate Computer programs that calculate the energy of various conformations of molecules and predict the lowest energy, to learn how to construct or draw representations of molecules using a molecular modeling program called HyperChem (HyperCube, Inc.), to perform geometry optimizations (energy minimizations) to determine the lowest energy conformations of molecules).

(Depending upon the availability of infrastructure facilities, instructor can demonstrate the students use of hyperchem software, Gaussian software – geometry optimization). They can be allowed for academic visit to computational labs to gain knowledge and a report may be considered for viva voce/examination). Open source softwares may be used for lab demonstration and students may prepare a report along with viva-voce shall constitute practical examination. Instructor may encourage the students to gain hand-on experience in using open-source softwares (for perfoming various calculation as mentioned) in lab computers, periodic evaluation of which can also be accepted as conducting lab practical examination. Basic idea is to encourage the students to get knowledge without keeping any rigid practical syllabus framework).

(Examples of the computational work that can be done: Compare the optimized C-C bond lengths in ethane, ethene, ethyne and benzene. Visualize the molecular orbitals of the ethane σ bonds and ethene, ethyne, benzene and pyridine π bonds.

ii. (a) Perform a conformational analysis of butane. (b) Determine the enthalpy of isomerization of *cis* and *trans* 2-butene.

iii. Visualize the electron density and electrostatic potential maps for LiH, HF, N_2, NO and CO and comment. Relate to the dipole moments. Animate the vibrations of these molecules.

(Software: ChemSketch, ArgusLab (www.planaria-software.com), TINKER 6.2 (dasher.wustl.edu/ffe), WebLab Viewer, Hyperchem, or any similar software.

(ii). Determination of indicator constant - colorimetry.

(iii). Verification of Beer's Law - Determination of concentration of solution by colorimetry.

Suggested books/reference books:

1.Essentials of computational chemistry – Theories and models, C. J. Crammer, Wiley, 2nd Edn.,

2.Principle and applications of quantum chemistry, V.K.Gupta, Elsevier, 2016.

3. Practicals in physical chemistry – a modern approach, P.S.Sindhu, Macmillan,

4. Experiments in Physical Chemistry, J.M.Wilson, R.J.Newcomb, A.R.Denaro, 2nd Edn., Elsevier.

5. A.R. Leach, *Molecular Modelling Principles and Application*, Longman, 2001.
6. J.M. Haile, *Molecular Dynamics Simulation Elementary Methods*, John Wiley and Sons, 1997.
7. Gupta, S.P. *QSAR and Molecular Modeling*, Springer - Anamaya Publishers, 2008.

11.Course course: Inorganic Chemistry-III

L	T	P	Cr
3	1	0	4

After completion of the course, the learner shall be able to understand:

Learning objective:

1. Coordination compounds – its nomenclature, theories, d-orbital splitting in complexes, chelate.
2. Transition metals, its stability, color, oxidation states and complexes.
3. Lanthanides, Actinides – separation, color, spectra and magnetic behavior
4. Bioinorganic chemistry – metal ions in biological system, its toxicity; hemoglobin.
5. Understanding the nomenclature of coordination compounds/complexes, Molecular orbital theory, d-orbital splitting in tetrahedral, octahedral, square planar complexes, chelate effects.
6. Understanding the transition metals stability in reactions, origin of colour and magnetic properties.
7. Understanding the separation of Lanthanoids and Actinoids, its color, spectra and magnetic behavior.
8. Understanding the bioinorganic chemistry of metals in biological systems.
9. Hemoglobin and its importance in biological systems.

Self-study:

1. IUPAC nomenclature of coordination compounds/complexes.
2. Prediction of structure of complexes using various theories; color and magnetic properties of different complexes.
3. Use of lanthanide/actinide compounds in industries.
4. Toxicity of various metals and mechanism of metal-biological system interactions.

Coordination Chemistry: (10 classes of 60 minutes duration each)

Werner's theory, EAN rule, piano-stool compounds, valence bond theory (inner and outer orbital complexes), Crystal field theory, d-orbital splitting, , weak and strong fields, pairing energies, factors affecting the magnitude of (Δ). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar complexes, d orbital splitting in trigonal bipyramidal, square pyramidal and cubic ligand field environments, CFSE, Variation of lattice energies, enthalpies of hydration and crystal radii variations in halides of first and second row transition metal series, Qualitative aspect of Ligand field theory, MO diagrams of representative coronation complexes, IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with the coordination number 4 and 6, Chelate effect,

Transition Elements: (10 classes of 60 minutes duration each)

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, and ability to form complexes. Stability of various oxidation states and e.m.f. (Latimer & Bsworth diagrams). Difference between the first, second and third transition series. Chemistry of Ti, V, Cr Mn, Fe and Co in various oxidation states (excluding their metallurgy)

Lanthanoids and Actinides: (10 classes of 60 minutes duration each)

Electronic configuration, oxidation states, color, spectra and magnetic behavior, lanthanide contraction, separation of lanthanides (ion-exchange method only).

Bioinorganic Chemistry: (10 classes of 60 minutes duration each)

Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on distribution of metals. Sodium / K-pump, carbonic anhydrase and carboxypeptidase. Excess and deficiency of some trace metals. Toxicity of metal ions (Hg, Pb, Cd and As), toxicity, chelating agents in medicine. Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

Recommended text books/References:

Purcell, K.F & Kotz, J.C. *Inorganic Chemistry* W.B. Saunders Co, 1977.

Huheey, J.E., *Inorganic Chemistry*, Prentice Hall, 1993.

Lippard, S.J. & Berg, J.M. *Principles of Bioinorganic Chemistry* Panima Publishing Company 1994.

Cotton, F.A. & Wilkinson, G, *Advanced Inorganic Chemistry* Wiley-VCH, 1999

Basolo, F, and Pearson, R.C. *Mechanisms of Inorganic Chemistry*, John Wiley & Sons, NY, 1967.
Greenwood, N.N. & Earnshaw A. *Chemistry of the Elements*, Butterworth-Heinemann, 1997.

11.1.Core course: Inorganic Chemistry Practical

L	T	P	Cr
0	0	2	2

1.Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given on understanding of the chemistry of different reactions. Following radicals may be analyzed:
Carbonate, nitrate, nitrite, sulphide, sulphate, sulphite, acetate, fluoride, chloride, bromide, iodide, borate, oxalate, phosphate, ammonium, potassium, lead, copper, cadmium, bismuth, tin, iron, aluminum, chromium, zinc, manganese, cobalt, nickel, barium strontium, calcium, magnesium. Mixtures containing one interfering anion, or insoluble component ($BaSO_4$, $SrSO_4$, $PbSO_4$, CaF_2 or Al_2O_3) **or** combination of anions e.g. $CO_3^{2-}$and SO_3^{2-}, NO_2^- and NO_3^-,Cl^- and Br^-, Cl^- and I^-, Br^- and I^-, NO_3^- and Br^-, NO_3^- and I^-. Spot analysis/tests should be done whenever possible.

2. Controlled synthesis of two copper oxalate hydrate complexes: kinetic vs thermodynamic factors.
3. Preparation of acetylacetanato complexes of Cu^{2+}/Fe^{3+}. (Also find the λ_{max} of the prepared complex using instrument).
4. Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g. bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

Recommended text books/references:

1. Vogel's *Qualitative Inorganic Analysis,* Revised by G. Svehla. Pearson Education, 2002.
2. Marr & Rockett *Practical Inorganic Chemistry.* John Wiley & Sons 1972.

12.Core course: Analytical Chemistry

L	T	P	Cr
3	1	0	4

After completion of the course, the student shall be able to understand:

Learning objective:

1. Familiarization with fundamentals of analytical chemistry.
2. Basics of spectroscopic, thermal, electrochemical techniques
3. Learning basics of separation techniques and its applications.
4. Understanding analytical tools, statistical methods applied to analytical chemistry.
5. Understanding principle of UV-Vis spectroscopy and its applications.
6. Understanding principles of thermo-gravimetric analysis and study of thermal decomposition of materials/characterization of materials.
7. Understanding basics of electro-analytical techniques and its applications.
8. Understanding principles of separation technology and its use in advanced instrumentations.

Self-study:

1. Thermo-gravimetric Analysis of different compounds and application of mathematical models.
2. Study of different kinds of chromatograms; calculation of R_f,
3. Analysis of GC/HPLC data for known materials/compounds.

Qualitative and quantitative aspects of analysis: (4 classes of 60 minutes duration each)

Tools in analytical chemistry and their applications, Sampling, evaluation of analytical data, errors, accuracy and precision, statistical test of data; F, Q and t-test, rejection of data, and confidence intervals.

Spectroscopy: (8 classes of 60 minutes duration each)
Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.

Vibration spectroscopy: Basic principles of instrumentation, sampling techniques. Application of IR spectroscopy for characterization through interpretation of data, Effect and importance of isotope substitution. Introduction to Raman spectra

UV-Visible Spectrometry: Basic principles of instrumentation, principles of quantitative analysis using estimation of metal ions from aqueous solution, Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method.

Thermal analysis: (6 classes of 60 minutes duration each)

Theory of thermogravimetry (TG and DTG), instrumentation, estimation of Ca and Mg from their mixture.

Electroanalytical methods: (6 classes of 60 minutes duration each)

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. determination of pKa values.

Separation techniques: (16 classes of 60 minutes duration each)

Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation. Technique of extraction: batch, continuous and counter current extractions. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and non-aqueous media.

Chromatography techniques: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange. Development of chromatograms: frontal, elution and displacement methods. Qualitative and quantitative aspects of chromatographic methods of analysis using LC, GLC, TLC and HPLC.

Recommended Books/Reference Books:

1 Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.,* Pearson, 2009.

2 Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing

California, USA, 1988.

Christian, G.D, *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.

4 Harris, D.C.: *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.

5 Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis, Saunder College Publications, (1998).*

6 Mikes, O. *Laboratory Hand Book of Chromatographic & Allied Methods*, Elles Harwood John Wiley 1979.

7 Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.

8 Khopkar, S. M., Basic Concepts of Analytical Chemistry, New Age (Second edition)1998

9.Skoog D.A., Holler F.J., Nieman T.A., Principles of instrumental analysis, 5th Edn., Brooks & Cole (1997).

12.1.Core course: Analytical Chemistry Practical

L	T	P	Cr
0	0	2	2

(Recommended to carry out at least two experiments from each section)

I. Chromatography:

(i) Paper chromatographic separation of Fe^{3+}, Al^{3+}, and Cr^{3+}.

(ii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R_f values.

iii. Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their R_f values.

(iv) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

II. Solvent Extractions:

(i) To separate a mixture of Ni^{2+} & Fe^{2+} by complexation with DMG and extracting the Ni^{2+}-DMG complex in chloroform, and determine its concentration by spectrophotometry.

ii. Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.

iii. Determination of Na, Ca, Li in cola drinks and fruit juices using flame photometric techniques.

III. Analysis of soil:

(i) Determination of pH of soil.

(ii) Total soluble salt

(iii) Estimation of calcium, magnesium, phosphate, nitrate

IV. Ion exchange:

(i) Determination of exchange capacity of cation exchange resins and anion exchange resins.

(ii) Separation of metal ions from their binary mixture.

(iii) Separation of amino acids from organic acids by ion exchange chromatography.

V. Spectrophotometry

(i). Determination of pKa values of indicator using spectrophotometry.

(ii) Structural characterization of compounds by infrared spectroscopy.

(iii) Determination of dissolved oxygen in water.

(iv) Determination of chemical oxygen demand (COD).

(v) Determination of Biological oxygen demand (BOD).

(vi) Determine the composition of the Ferric-salicylate/ ferric-thiocyanate complex by Job's method.

Recommended text books/references:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.*, Pearson, 2009.

2. Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.

3. Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.

4. Harris, D.C. *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.

5. Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. New Age International Publisher, 2009.

6. Skoog, D.A. Holler F.J. and Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Edition.

7. Mikes, O. & Chalmes, R.A. *Laboratory Handbook of Chromatographic & Allied Methods*, Elles Harwood Ltd. London.

8. Ditts, R.V. *Analytical Chemistry: Methods of separation.* Van Nostrand, New York, 1974.

13.Core course: Green Chemistry

L	T	P	Cr

3	**1**	**0**	**4**

After completion of the course, the learner shall be able to understand:

Learning objective:

1. Green chemistry and its principles.
2. Green synthesis and reactions.
3. Green chemistry for sustainable solutions.
4. Understanding principles of green chemistry.
5. Understanding design of chemical reactions/chemical synthesis using green chemistry principles.
6. Atom economy and design of chemical reactions using the principle.
7. Understanding the use of green chemistry principle and processes in laboratory reactions.

Self-study:

1. Use of green chemistry in designing new laboratory experiments.
2. Use of principle of atom economy and design experiments using the principle.
3. Use of green chemistry in combinatorial chemistry and biomimetic catalyst.

Introduction to Green Chemistry (4 classes of 60 minutes duration each)
Basic introduction and explaining goals of Green Chemistry. Limitations/Obstacles in the pursuit of the goals of Green Chemistry

Principles of Green Chemistry and Designing a Chemical synthesis (12 classes of 60 minutes duration each)
Twelve principles of Green Chemistry with their explanations and examples and special emphasis on Designing a Green Synthesis using these principles (Prevention of Waste/ byproducts; maximum incorporation of the materials used in the process into the final products, Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions).

Green Synthesis / Reactions: (16 classes of 60 minutes duration each)

1. Green Synthesis of adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis).

2. Microwave assisted reactions in water: (Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols) and reactions in organic solvents (Diels-Alder reaction and Decarboxylation reaction).

3. Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)

4 Surfactants for carbon dioxide – replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments.

5 Designing of Environmentally safe marine antifoulant.

6 An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn.

7 Healthier Fats and oil by Green Chemistry: Enzymatic Inter esterification for production of no Trans-Fats and Oils

Future Trends in Green Chemistry (8 classes of 60 minutes duration each)

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; co crystal controlled solid state synthesis (C_2S_3); Green chemistry in sustainable development.

Recommended Books/References:

1.Ahluwalia, V.K., Kidwai, M.R. *New Trends in Green Chemistry*, Anamalaya Publishers (2005).

2. Anastas, P.T. & Warner, J.K, *Green Chemistry- Theory and Practical*, Oxford University Press (1998).

3. Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).

4. Cann, M.C.and Connely, M.E. *Real-World cases in Green Chemistry*, ACS (2000).

5. Ryan, M.A. and Tinnesand, M. *Introduction to Green Chemistry*, American Chemical Society, (2002).

6. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, Second Edition, 2010.

13.1.Core course: Green Chemistry Practical

L	T	P	Cr
0	0	2	2

(Following is the list of suggestive experiments. However, depending upon available resources, experiments may be added/changes may be incorporated): (six experiments may be conducted)

1. Preparation and characterization of nanoparticles of gold using tea leaves.

2. Preparation of biodiesel from vegetable/ waste cooking oil.

3. Use of molecular model kit to stimulate the reaction to investigate how the atom economy illustrates Green Chemistry.

4. Reactions like addition, elimination, substitution and rearrangement may also be studied for the calculation of atom economy.

5. Benzoin condensation using Thiamine Hydrochloride as a catalyst (instead of cyanide).

6. Extraction of D-limonene from orange peel using liquid CO_2 prepared form dry ice.

7. Mechanochemical solvent free synthesis of azomethines

8.Solvent free, microwave assisted one pot synthesis of phthalocyanine Cu(II) complex.

9. Photoreduction of benzophenone to benzopinacol in presence of sunlight.

Recommended Books/References:

1. Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice*, Oxford University Press (1998).

2. Kirchoff, M. & Ryan, M.A. *Greener approaches to undergraduate chemistry experiment*. American Chemical Society, Washington DC (2002).

3. Ryan, M.A. *Introduction to Green Chemistry*, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).

4. Sharma, R.K.; Sidhwani, I.T. and Chaudhari, M.K. I.K. Green Chemistry Experiment: A monograph, International Publishing ISBN 978-93-81141-55-7 (2013).

5. Cann, M.C. and Connelly, M. E. *Real world cases in Green Chemistry*, American Chemical Society (2008).

6. Cann, M. C. and Thomas, P. *Real world cases in Green Chemistry,* American Chemical Society (2008).

7. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, Second Edition, 2010.

8. Pavia, D. L., Lampman, G.M., Kriz, G.S. & Engel, R.G. *Introduction to Organic Laboratory Techniques: A Microscale and Macro Scale Approach,* W.B.Saunders, 1995.

14.Core course: Chemistry of Materials

L	T	P	Cr
3	1	0	4

After completiton of the course, the learner shall be able to understand:

Learning objective:

1. Crystalline solids – parameters, symmetry.
2. Silica based materials in applications.
3. Technological importance of ionic liquids, preparation of materials– using sol-gel technique.
4. Nano-structured materials, self-assembled structure.
5. Composites and its applications
6. Understanding basic parameters of crystalline solids, symmetry and crystal structures.
7. Mesoporous/microporous silica based materials, functionalized hybrid materials and its applications.
8. Preparation of inorganic solids, host-guest chemistry, ionic liquids and its significance.
9. Understanding self-assembled structures, nano-structured materials, carbon nanotubes, applications.
10. Understanding composites and their industrial applications.

Self-study:

1. Hybrid materials/functionalized hybrid materials and their applications in industry.
2. Applications of nano-structured materials in targeted drug delivery/pharmaceutical applications/industrial applications.
3. Use of composites in industry.

Basics of crystalline solids (8 classes of 60 minutes duration each)

Crystalline solids, crystal systems, Bravais lattices, coordination number, packing factors – cubic, hexagonal, diamond structures, lattice planes, Miller indices, interplanar distances, directions, types of bonding , lattice energy, Madelung constants, Born Haber cycle, cohesive energy, Symmetry elements, operations , translational symmetries - point groups, space groups, equivalent positions, close packed structures, voids, crystal structures, Pauling rules, defects in crystals, polymorphism, twinning.

Silica based materials: **(8 classes of 60 minutes duration each)**

Introduction to Zeolites, metallosilicates, silicalites and related microporous materials, Mesoporous silica, metal oxides and related functionalized mesoporous materials: Covalent organic frameworks, Organic-Inorganic hybrid materials, periodic mesoporous organo silica, metal organic frameworks: H_2 /CO_2 gas storage and catalytic applications

Inorganic solids/ionic liquids of technological importance: (8 classes of 60 minutes duration each)

Preparation of inorganic solids: Conventional heat and beat methods, Co-precipitation method, Sol-gel methods, Hydro-thermal method, Ion-exchange and Intercalation methods. Introduction to Solid electrolytes, inorganic liquid crystals. Ionic liquids, forces responsible for ionic liquids, synthesis and application of imidazolium and phosphonium based ionic liquids. Host-guest chemistry (elementary ideas).

Nanomaterials: (8 classes of 60 minutes duration each)

Overview of nanostructures and nano-materials: classification. Preparation of gold and silver metallic nanoparticles, self-assembled nanostructures-control of nano-architecture-one dimensional control. Carbon nanotubes and inorganic nanowires.

Composite materials: (8 classes of 60 minutes duration each)

Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix composites, fibre-reinforced composites, environmental effects on composites, applications of composites.

Recommend books/References:

1.Atkins P, Overton T., Rourke J. Weller M. and Armstrong F *Shriver and Atkins. Inorganic Chemistry* Oxford University Press, Fifth Edition, 2012.

3. Adam, D.M. *Inorganic Solids: An introduction to concepts in solid-state structural chemistry*. John Wiley,1974.
4. Poole, C.P. & Owens, F.J. *Introduction to Nanotechnology* John Wiley 2003.

5. Rodger, G.E. *Inorganic and Solid State Chemistry*, Cengage Learning, 2002.

14.1. Materials Chemistry Practical

L	T	P	Cr
0	0	2	2

(The list of experiments are suggestive. However, faculties/academic bodies may add more experiments/references or incorporate suitable revisions based on infrastructure facilities available).

1. Preparation of urea-formaldehyde resin
2. Preparations of novalac resin/resol resin
3. Synthesis of materials/porous materials (Sol-gel, hydrothermal, microwave). (Similarly other materials synthesis can be designed).
4. Preparation of silver nano material. (Similarly other nano materials of other metals synthesis can be designed).
5. Analysis of XRD pattern of crystals.
6. Interpretation of FTIR, NMR and UV-Vis data of given material.
7. Estimation of particle size from the BET, SEM techniques.
8. Density measurement of ionic liquids
9. Determining dynamic viscosities of given ionic liquids
10. Determination of hydration number IR spectra.

DISCIPLINE SPECIFIC ELECTIVE COURSES

These courses have the following credit pattern.

For Theory based courses:

L	T	P	Cr
3	1	0	3

For laboratory based courses:

L	T	P	Cr
0	0	2	2

1. Medicinal Chemistry

L	T	P	Cr
3	**1**	**2**	**6**

After completion of the course, the learner can be able to understand:

1. The basics of medicinal chemistry, biophysical properties
2. Biological activity parameters
3. Drug metabolism
4. Biophysical and chemical properties of enzymes, hormones, vitamins
5. Concept of rational drug design

Bio-physicochemical properties

Acidity/Basicity, Solubility, Ionization, Hydrophobic properties, Hydrophilic properties, Lipinski Rule, Drug-like properties, Understanding of the biological activity parameters such as K_i, K_d, LD_{50}, EC_{50}, IC_{50}, CC_{50}, ADMET properties

Structural properties

Isosterism, Bioisosterism, Nonclassical isosteres, Understanding of the 3D-structure along with bond length, bond angle and dihydral angle, Concept of Configuration and Conformation with examples, Concept of stereochemistry in terms of biological response with examples, Stereoselective receptors or enzymes such as muscarinic receptor, Stereochemically pure drug and recemates, Examples such as catecholamines, etc.

Drug target understanding

Metabolism, Drug metabolism, Anti-metabolite, Enzyme inhibitor, Agonist, Antagonist, Examples.

Medicinal Chemistry of Therapeutic Agent

Structure, Chemistry, Mode of action and adverse effect of the representative therapeutic agents such as Anti-infective agent, Antimalarials, Antibacterial, Antiviral, Anticancer, CNS acting drugs, Adrenergic Agents, Cholinergic Drugs, Diuretics, Cardivascular, local anesthetic agent, Analgesic Agents, Histamine and Antihistamine agents

Steroids, Prostaglandins, Enzyme, Hormone and Vitamins

Biophysico-chemical properties, Steroid Hormone Receptors, Chemical Contraceptive agents, COX-2 inhibitors, Prostaglandins for Ophthalmic use, pharmaceutically important enzyme products such as Pancreatin, Trypsin, Insulin. Classification of vitamins with examples.

Concept of rational drug design

Structure activity relationship, Drug-receptor understanding, Molecular modeling, Structure based drug design. QSAR.

Recommended books/References:

1. Wilson and Gisvold's Textbook of Organic Medicinal and Pharmaceutical ...by Charles Owens Wilson, John H. Block, Ole Gisvold, John Marlowe Beale
2. Foye's Principles of Medicinal Chemistry by David A. Williams, Thomas L. Lemke, William O. Foye (2008), Kluwer publication.
3. Remington: The Science and Practice of Pharmacy Vol 1, Ed. 19 by Joseph Price Remington, Alfonso R. Gennaro. (1995), MACK Publishing.
4. Burgers Medicinal Chemistry by Manfred E. Wolff, Alfred Burger
5. Burgers Medicinal Chemistry and Drug Discovery by Abraham D. J., Lewis F. L., Burger A., vol.5, 6th Edn., 2003, Hoboken N.J.Wiley,
6. The Organic Chemistry of Drug Design and Drug Action by Silverman R. B., 2nd Edn., Academic Press. 2012.

7. Exploring QSAR: Fundamental and applications in Chemistry and Biology by Hansch C. and Leo, A American Chemical Society (1995)
8. Patrick, G. Medicinal Chemistry, Oxford.University Press (2000)

Practical wok suggested:

1.Purification Techniques of Solvents by Fractional Distillation and Vacuum Distillation

2.Thin Layer Chromatography Technique and Purification of commercially available drugs/Synthesized Compounds by Column Chromatography.

3. Preparation of Acid/Basic Salts of Drugs and Evaluation of their Physicochemical Properties.(Benzilic Acid & Sodium Benzoate)

4.Synthesis & Purification of following Compounds using:

(i)Precipitation or Recrystallization.

(ii)Synthesis of Benzimidazole.

(iii)Synthesis of Anthranilic Acid.

(iv)Synthesis of Sulphanilamide.

(v)Synthesis of benzoic acid from benzyl alcohol.

(vi)Synthesis of 1,4 – dihydropyridine.

5.Computational modeling of drug design/use of softwares may be demonstrated to students.

Suggsted books/references:

1.Vogel's Textbook of Quantitative Chemical Analysis, J. Mendham, R.C. Denney, J. D. Barnes, M. J. K Thomas, 6th Edition, Pearson’s Education Ltd.

2.Advanced Practical Medicinal Chemistry, Ashutosh Kar, New Age International Ltd. (2004).

3.Vogel‟s Textbook of Practical Organic Chemistry, B. S. Furniss, A. J. Hannaford , P.W.G. Smith, A. R Tatchell, 5th edition (2008), Pearson’s Education Ltd

(The list of experiments and books are purly suggestive; University/institute may incorporate further changes in number of experiments and books/refererences (updated version from time to time) based on course design and available infrastructure facilities).

2. Electrochemistry

L	T	P	Cr
3	1	2	6

After completion of the course, the learner can be able to understand:

1.Basic principle of laws of electrochemistry.

2 Understanding about chemical cells and their function

3 Understanding about electrodes, EMF measurement.

4 Understanding about potentiometric titrations and their applications.

Unit-I

Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Hückel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden's rules. Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

Unit-II

Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry. Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb2O3 electrodes. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

Unit-III: Electroanalytical methods: Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

Unit-IV: Electrical & Magnetic Properties of Atoms and Molecules: Basic ideas of electrostatics, Electrostatics of dielectric media, Clausius-Mosotti equation, Lorenz-Laurentz equation, Dipole moment and molecular polarizabilities and their measurements. Diamagnetism, paramagnetism, magnetic susceptibility and its measurement, molecular interpretation.

Recommended books/reference books

1.Atkins, P.W & Paula, J.D. Physical Chemistry, 10th Ed., Oxford University Press (2014).
2.Castellan, G. W. Physical Chemistry 4th Ed., Narosa (2004).
3.Mortimer, R. G. Physical Chemistry 3rd Ed., Elsevier: NOIDA, UP (2009).
4.Barrow, G. M., Physical Chemistry 5th Ed., Tata McGraw Hill: New Delhi (2006).
5.Engel, T. & Reid, P. Physical Chemistry 3rd Ed., Prentice-Hall (2012).
6.Rogers, D. W. Concise Physical Chemistry Wiley (2010).
7.Silbey, R. J.; Alberty, R. A. & Bawendi, M. G. Physical Chemistry 4th Ed., John Wiley & Sons, Inc. (2005).

List of suggested laboratory experiments

1.Determination of pH of a given solution using glass electrode.
2. Determination of cell constant.
3. Determination of equivalent conductance, degree of dissociation, and dissociation constant of weak acid.
3. Conductometric titration : strong acid *vs*. strong base, weak acid *vs*. strong base.
4. Potentiometric titration : strong acid *vs*. strong base, weak acid *vs*. strong base, potassium dichromate vs. mohr's salt.

Recommended books/reference books:

1.Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).

2.Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry,* Universities Press.

3.Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.;* McGraw-Hill: New York (2003).

4. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.;* W.H. Freeman & Co.: New York (2003).

3. Polymer Chemistry

L	T	P	Cr
3	1	2	6

After completion of the course, the learner can be able to understand:

1. The mechanism of polymer material formation.
2. Molecular weight and structure property relationship
3. Polymerization procedure and Zigler-Natta catalysis.
4. Characterization of polymers

Introduction

Polymer, monomer, examples of polymers, biopolymers, classification, polymerization process, degree of polymerization, condensation, addition polymers, kinetics of addition polymerization process.

Polymeric Structure and Property Relationship

Structure of polymers - Linear, branched, cross linked, and network polymers, molecular weight (number average, weight average, viscosity average) and distribution of molecular weight, polydispersity index, crystallinity in polymer, melting temperature and glass transition temperature, Volumetric properties - molar volume, density, Van der Waals volume - Coefficient of linear thermal expansion and volumetric thermal expansion - Pressure volume temperature (PVT) relationship.

Polymerization Chemistry

Industrial methods of polymerization such as a bulk, solution, emulsion, suspension. Stereochemistry of polymers and stereo-specific polymerization, Catalysts-their utility in polymers and stereo-specific polymerizations, Catalysts their utility in polymer manufacture, Zieglar-Natta, Metallocene and others.

Characterization of Polymers

Molecular Weight Determination by Light Scattering, Osmometry, End-Group Analysis, Viscosity, Gel Permeation Chromatography; Application, of FTIR, UV-visible, NMR, and Mass Spectroscopy for Identification of polymers.

Recommended books/References:

1. D.W. Van Krevelen and P.J. Hoftyzen, "Properties Of Polymer, 3rd Edition Elsevier Scientific, Publishing Company Amsterdam - Oxford - Newyork. 1990.
2. J.E. Mark Ed.AIP, Physical Properties Of Polymers Hand Book, Williston, Vt, 1996.
3. Reaction Engineering of Step Growth Polymerization, S K Gupta and Anil Kumar, Plenum Press, 1987
4. Odian; George, Principles of Polymerization, McGraw-Hill Book Co., New York (1970).
5. W. Billmeyer, Text book of polymer science, 3rd Edn., 2007, Wiley.
6. J.R.Fried, Polymer Science and Technology, (2005), PHI publication.
7. Billmeyer Jr.; Fred W., Textbook of Polymer Science, Wiley- Interscience Publishers, New York (1962).

List of suggested laboratory practicals

1.Free radical solution polymerization of any one: Styrene, methylmethacrylate, methyl acrylate, methacrylic acid (using free radical initiators). (purification of monomer should be taught)

2. Preparation of phenol-formaldehyde resins

3. Emulsion polymerization of polymethylmethacrylate.

4. Use of viscometer for molecular weight determination – (any known polymer, example: polyvinyl pyrrolidone in water/polyacrylamide in $NaNO_2$ solution) by viscometry. (students should be explained regarding principles and use of ubblohde/ostwald viscometer).

5. Estimation of amount of HCHO in a given solution by sodium bisulphite method.

6. Use of FTIR/TGA/DSC – for polymer characterization (may be demonstrated to students)

7. Determination of exchange capacity of cation exchange resins and anion exchange resins.

Recommended Books/Reference books

1.P. Munk & T.M. Aminabhavi, *Introduction to Macromolecular Science*, 2nd ed. John Wiley & Sons (2002).

2.M.P. Stevens, *Polymer Chemistry: An Introduction* 3rd ed. Oxford University Press (2005).

3. L. H. Sperling, *Introduction to Physical Polymer Science,* 4th ed. John Wiley & Sons (2005)

(The list of experiments and books are purly suggestive; University/institute may incorporate further changes in number of experiments and books/refererences (updated version from time to time) based on course design and available infrastructure facilities).

4. Environmental Chemistry

L	T	P	Cr
3	1	2	6

After completion of the course, the learner can be able to understand:

1.Compositon of atmosphere

2.Biogeochemical cycles

3.Hydrological cycle

4. Water quality parameters

5.Atomospheric chemical phenomon and environmental pollution

6. Water pollution, parameters of water pollution, treatment of polluted water.

Environment

Composition of atmosphere, temperature variation of earth atmospheric system (temperature vs. altitude curve), biogeochemical cycles of C, N, P, S and O system.

Hydrosphere: Hydrological cycle, aquatic pollution and water quality parameters – Dissolve oxygen, biochemical oxygen demand, chemical oxygen demand, Analytical methods for the determination fluoride, chromium and arsenic, residual chlorine and chlorine demand, purification and treatment of municipal water and waste water.

Atmosphere

Chemical composition of atmosphere – particle, ions, and radicals in their formation, chemical and photochemical reactions in atmosphere, smog formation, oxides of N, C, S, and O and their effect, pollution by chemicals, CFC, Green House effect, acid rain, air pollution and control.

Aquatic chemistry

Water and its necessities, various water quality parameters (DO, BOD, COD, conductivity, pH, alkalinity, hardness) and its determination, Industrial, municipal water treatment processes, Waste water treatment procedure (primary, secondary and tertiary), Solid waste treatment. Soil pollution and Noise pollution.

Recommended Books/References:

1. De.A.K.Environmental Chemistry, Wiley Eastern Ltd, 1990.
2. Miller T.G.Jr., Environmental Science, Wadsworth publishing House, Meerut Odum.E.P.1971.
3. Odum, E.P. (1971) Fundamentals of Ecology. Third Edition, W.B. Saunders Co., Philadelphia
4. S. E. Manahan, Environmental chemistry, 1993, Boca Raton, Lewis publisher
5. Environmental chemistry, Sharma and Kaur, 2016, Krishna publishers
6. Environmental Pollution, Monitoring and control, S.M. Khopker, 2007, New Age International.
7. Environmental chemistry, C. Baird, M. Cann, 5th Edn, 2012, W.H.Freeman publication.

9 G. S. Sodhi Fundamental Concepts of Environmental Chemistry (Third Edition) Narosa (2009).

10. Principles of instrumental analysis: D. A. Skoog, Fifth Edition, Sauns College Publishing (London)

11 Basic concepts of analytical chemistry: S. M. Khopkar, Wiley Eastern (1995)

List of suggested laboratory practicals

Determination of water quality parameters in following aspect:

1. Determination of dissolved oxygen in given water (chemical method/instrumentation method).

2.Determination of Biological Oxygen Demand (BOD_5).

3. Determination of Chemical Oxygen Demand (COD).

4. Finding out percentage of available chlorine in bleaching powder.

5. Measurement of chloride, sulphate and salinity of water samples by titration method ($AgNO_3$ and potassium chromate).

6. Estimation of total alkalinity of water samples (carbonate, bicarbonate) by titration method.

7. Estimation of SPM in air samples.

List of Recommended books/Reference Books:

1. R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, John Wiley & Sons, Inc. Publishers, New Delhi.(2005 edition).

3. J. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.

4. S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.

5. A. K. De, *Environmental Chemistry*: New Age International Pvt., Ltd, New Delhi.

6. S. M. Khopkar, *Environmental Pollution Analysis*: New Age Int. Publisher, New Delhi.

(The list of experiments and books are purly suggestive; University/institute may incorporate further changes in number of experiments and books/refererences (updated version from time to time) based on course design and available infrastructure facilities).

5. Advanced Materials Chemistry

L	T	P	Cr
3	1	2	6

Crystal structure of solids

Fundamental of lattices, unit cell, atomic coordinates, Bravais lattices, crystal direction and planes, types of close packing, packing efficiency, radius ratios; few important crystal structures.

Synthesis of Inorganic solids; solid state, solution phase and vapor phase synthesis; precipitation, hydrothermal, sol-gel, surfactant based synthesis. Growth of single crystals.

Crystal structure determination by X-ray diffraction, d-spacing formula, symmetrically absent reflections, Multiplicities, Scattering of X-rays by an atom and a crystal. Single crystal and powder diffraction. Electron and neutron diffraction. Concept of reciprocal lattice. Electron microscopy techniques.

Nanomaterial fundamentals

Synthesis: Bottom-up vs. Top-down Methods. Solution phase synthetic methods. Role of surfactant in shape and size control of nanomaterials. Synthesis of nanowires and nanotubes by CVD and MOCVD method.

Nanomaterials Characterization: XRD of nanomaterials, Electron microscopy (SEM, TEM, HRTEM and EDX) of nanomaterials, Scanning probe microscopy.

Nanomaterial properties and applications: Magnetic properties of nanoparticles; superparamagnetism, ferromagnetism in antiferromagnetic nanoparticles and single domain to multidomain transition. magnetic nanoparticles as MRI contrast agents.

Frontier areas of polymer science and technology

Conducting polymers: basic principles of conducting polymers, delocalized electronic states of conjugated polymers, polyanilines, polyacetylenes, polythiophene, applications of conducting polymers.

Biodegradable polymers: Definition classification of natural biodegradable polymers, cellulose, cellulose acetate, cellophane, soy protein, corn, zein protein, wheat gluten protein, synthetic biodegradable polymers, polyhydroxy alkanoates, polycarpolactone, poly(vinyl alcohol), polyacetic acid, application of biodegradable and biomedical polymers, contact lens, dental polymers, artificial heart, kidney, skin, and blood cells.

Fibers: natural fibers, cotton, wool, silk, rayon, artificial fibers, polyamides, acrylic acid, PVC, PVA.

Rubber: Compounding and elastomeric properties, vulcanization, reinforcement.

Recommended books/References:

1. Zhen Guo and Li Tan, *Fundamentals and Applications of Nanomaterials*.2009, Artech House, London Publication.
2. Physical methods for chemistry: R. S. Drago, 1992, Saunders college publication.
3. Polymer science, V. R. Gowariker, N. V.Viswanathan, J. Sreedhar, New Age International (P) Ltd., 2015.
4. P. J. Flory, Principle of polymer chemistry, Cornell University Press.
5. Polymer Science and technology, Plastics, Rubber and composites, P. Ghosh, Tata McGraw Hill.
6. V. Gowriker, N. V. Viswanathan, J. Sreedhar, Polymer Science, New Age Int.Publication, 2019.

List of suggested Laboratory Experiment.

(The list of experiments are suggestive. However, faculties/academic bodies may add more experiments/references or incorporate suitable revisions based on infrastructure facilities available).

1. Preparation of gold and silver nano-particles.

2. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein

3. Determination of composition of dolomite (by complexometric titration).

4. Analysis of XRD pattern of few selected crystals like $NaNO_3$, $CaCl_2$, etc.; Indexing of a given powder diffraction pattern of a cubic crystalline system.

5. Interpretation of FTIR, NMR and UV-Vis data of given material.

6. Estimation of particle size from the BET, SEM techniques.

Recommended books/Reference Book:

1.Fahlman, B.D. *Materials Chemistry*, Springer, 2004.

6. Advanced Analytical Chemistry

L	T	P	Cr
3	1	2	6

Statistical methods in chemical analysis

Theory of error and treatment of quantitative data, accuracy and precision, ways of expressing accuracy and precision, Normal error curve and its equation. Useful statistical tests with equation, test of significance, the F-test, the students t-test, the Chi-test, the correlation coefficient, confidence limit of the mean, comparison of two standard values, comparison of two standard values, comparison of standard deviation with average deviation, comparison of mean with true values, regression analysis (least square method).

Polarography

Current-voltage relationship, theory of polarographic waves, instrumentation, qualitative and quantitative applications.

Atomic spectroscopy

Atomic absorption spectroscopy, theory and application (with some examples).

Thermal analysis

Theory, methodology, instruments and applications of theromogravimetric analysis (TGA/DTA), and differential scanning calorimetry (DSC).

Chromatography

Principles of chromatography, paper, column and thin layer chromatography, Gas-liquid chromatography, HPLC.

Analysis of fuel and drugs

Fuel analysis: Solid, liquid and gaseous fuels, ultimate and proximate analysis of solid fuel, Determination of calorific value of solid, liquid and gaseous fuels, Flash point and fire point.

Drug analysis: Classification of drugs, Analysis of some standard drug using various chromatographic techniques.

Recommended books/references:

1 Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.*, Pearson, 2009.

2 Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing California, USA, 1988.

3.Christian, G.D, *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.

4 Harris, D.C.: *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.

5 Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*

6 Mikes, O. *Laboratory Hand Book of Chromatographic & Allied Methods*, Elles Harwood John Wiley 1979.

7 Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.

8 Khopkar, S. M., Basic Concepts of Analytical Chemistry, New Age (Second edition) 1998

List of suggested laboratory experiments

1.Study the effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures. Preparation of buffer solutions of different pH (i. Sodium acetate-acetic acid, ii. Ammonium chloride-ammonium hydroxide

2. Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:

i. Ni (II) and Co (II)

ii. Fe (III) and Al (III)

3.Chromatographic separation of the active ingredients of plants, flowers and juices by TLC.

4. IR/DSC analysis of known polymer sample (for students demonstration only)

5. Determination of flash point & fire point of given fuel sample.

6. Determination of viscosity index, cloud point, pour point of given fuel sample.

7. Determination of calorific value of given fuel sample/coal sample using bomb calorimeter.

8. Proximate analysis of given coal sample.

9. Determination of the iodine number of oil.

10. Determination of the saponification number of oil.

Recommended books/Reference books:

Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.,* Pearson, 2009.

Jain, P.C. & Jain, M. *Engineering Chemistry* Dhanpat Rai & Sons, Delhi.

Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. New Age International Publisher, 2009

Skoog, D.A. Holler F.J. and Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Edition.

7. Nuclear & Radiation Chemistry

L	T	P	Cr
3	1	2	6

Nucleus and its classification, nuclear forces, nuclear stability, binding energy, nuclear models. Radioactive decay (Radioactive elements, general characteristics of radioactive decay, decay kinetics - decay constant, half life, mean life period), units of radioactivity, Transient and secular equilibria, Carbon dating and its usefulness.

Nuclear reactions: Bethe notation, types of nuclear reactions (n, p, α, d and γ), conservation of quantities (mass-energy and linear momentum) in nuclear reactions, reaction cross-section, compound nucleus theory and nuclear reactions. Nuclear fission: the process, fragments, mass distribution, and fission energy.

Measurement of radioactivity, idea about accelerator and detectors, Van de Graaaf and linear acceletors, synchrontrons, Geiger-Muller detector, Scintillaton detectors, Type of nuclear reactions, Nuclear fission, Nuclear fusion, Nuclear reactor: classification of reactors, the natural uranium reactor, breeder reactor. Nuclear fusion and stellar energy.

Radiation chemistry: Elementary ideas of radiation chemistry, radiolysis of water and aqueous solutions, unit of radiation chemical yield (G-value), radiation dosimetry (Fricke's dosimeter), units of radiation energy (Rad, Gray, Rontgen, RBE, Rcm, Sievert)

Nuclear pollution and Radiological safety: Interaction of radiation with matter, Radiolysis of water, Radiation dosimetry. Radioactive isotopes and their applications, Isotopic dilution analysis, Neutron activation analysis, diposal of nuclear waste, nuclear disaster and its management (nuclear accidents and holocaust – discussion about case studies).

Recommended Books/references:

1. Friendlander G, Kennedy G and Miller J. M. Nuclear and Radiochemistry, Wiley Interscience
2. Harvey, B. G. Introduction to Nuclear Physics & Chemistry, Prentice – Hall,
3. Overman R. T, Basic concept of Nuclear Chemistry, Chapman & Hall.
4. A. N. Nesmeyanov, Radiochemistry, MIR Publication, Moscow.
5. Spinks J. W. T. and Woods R. J. An Introduction to Radiation Chemistry, Wiley
6. Arnikar H. J., Essentials of Nuclear Chemistry, Wiley Eastern, Second Edition.

Suggested laboratory practicals:

1.The safe laboratory use of radionuclide and radioisotopes
2. demonstration of activity on Geiger-Muller and scintillation based counter.
3.liquid scintillation counting, alpha spectrometry, gamma spectrometry – to identify and quantify radioisotopes
4. occurrence of radon daughter particles in environmental samples.
5. Liquid-liquid separation/extraction of radio nuclide from environmental samples/water samples.
6. Isotopic application in removal process adsorption / ion exchange.

(The above list is just suggestive. More experiments can be added/incorporated based on facility/expertise available. Since above experiments require certified labs which may not be available at all places, therefore, it is advised that institute/university/teacher may arrange/allow academic visit of students to nuclear chemistry labs in the country following proper procedure and to prepare comprehensive report of the visit/viva voce of students which can also form a lab course until available facilities are available).

8. Organic Spectroscopy

L	T	P	Cr
3	1	2	6

Basic Principles of UV Spectroscopy:

Application of Woodward-Fiser rule in interpretation of Organic compounds: Application of visible, ultraviolet and infrared spectroscopy in organic molecules. Electromagnetic radiation, electronic transitions, λmax & εmax, chromophore, auxochrome, bathochromic and hypsochromic shifts. Application of electronic spectroscopy and Woodward rules for calculating λmax of conjugated dienes and α,β – unsaturated compounds.

Basic principles of IR Spectroscopy:

Identification of Functional groups of various classes of organic compounds: Infrared radiation and types of molecular vibrations, functional group and fingerprint region. IR spectra of alkanes, alkenes and simple alcohols (inter and intramolecular hydrogen bonding), aldehydes, ketones, carboxylic acids and their derivatives (effect of substitution on >C=O stretching absorptions).

NMR (^{1}H and ^{13}C NMR):

Application of Chemical Shifts, Splitting of signals, Spin coupling and Over Houser effect in interpretation of NMR spectra, Isotopic exchange

Basic principles Mass Spectrometry:

Application of fragmentation rule in characterization of organic compounds. Problems on structure elucidation of organic compounds based on spectral data.

Recommended Books/References:

1. R.M. Silverstein, G.C. Bassler & T.C. Morrill*: Spectroscopic Identification of Organic Compounds*, John Wiley & Sons.

2.John R. Dyer, Applications of absorption spectroscopy of organic compounds, Prentice Hall India (2012).

Suggested laboratory experiments

1.Purification method for liquid, solid organic substance (distillation, recrystallization, chromatorgrapy)

2.Analysis of spectra of UV-Vis, FTIR, NMR and Mass of simple organic compounds. (students may encourage to prepare simple organic compounds following given protocol (azodyes, acetanilides, benzoic acid, etc.) (or may use commercially available organic componds) and can be trained to identify/analyze important peaks/functionality, determine mass of the molecules (mass-spectra). They can submit a report regarding their analysis to course teacher.

9. Heterocyclic Chemistry

L	T	P	Cr
3	1	2	6

Heterocyclic Chemistry

Three-membered rings with one heteroatom: Chemistry of oxiranes, aziridines and episulphides - synthetic approaches and reactivities.

Three-membered heterocycles with two heteroatoms: oxaziranes, diaziridines and diazirines - synthetic approaches and reactivities.

Four-membered heterocycles: oxitanes, azatidanes and thietanes - synthetic approaches and reactivities. natural products:synthesis of Peniciline and cephalosporine.

Five-membered aromatic heterocycles:

1. With one heteroatom: furans, pyrroles and thiophenes - general synthetic approaches, properties and reactivities.
2. With two heteroatoms: oxazoles, isoxazoles, imidazoles, thiazoles, pyrazoles and isothiazoles - general synthetic approaches and reactivities.
3. With three and four heteroatoms: triazoles and tetrazoles - synthetic approaches, properties and reactivity.

Condensed five-membered Heterocycles:

Benzofuran, indoles and benzothiazoles - general synthetic approaches, with greater emphasis on the chemistry of Indoles.

Recommended Books/references:

1. Heterocyclic Chemistry, J.A. Joule, K. Mills, Wiley, 2010.
2. The Essence of heterocyclic Chemistry, A. R. Parikh, H. Parikh, R. Khunt, New Age Int. Publication,
3. Principles of Modern Heterocyclic Chemistry, L. A. Paquette, W. A. Benjamin, New York, 1968.
4. Heterocyclic Chemistry, J.A. Joule and G. F. Smith, van Nostrand, London, 1978.

5. Comprehensive Heterocyclic Chemistry. The structure, reactions, synthesis and use of Heterocyclic compounds, (Ed. A.R. Katritzky and C. W. Rees),. Vol 1-8, Pergamon Press, 1984.
6. Handbook of Heterocyclic Chemistry, A. R. Katritzky, Pergamon Press, 1985.
7. Van der plas, H. C. Ring transformations of Heterocycles, Vols 1 and 2, Academic Press, 1974.

List of suggested laboratory experiments

1.Identification of hetero atoms (S, N, X) in given organic compounds in lab.

2. Identification/separation of simple organic compounds containing hetero atoms using column chromatorgapy/TLC) in lab.

3. Spectroscopic identification of simple organic compounds (spectra may be provided to the students and teachers may help the students to identify the compounds using spectra). Melting point/boiling point of the compounds may be checked for its purity.

4. Teacher may guide the students for preparation of : Indigo (using aldol condensation reaction of 2-nitrobenzaldehyde with acetone in basic condition);

(Depending upon laboratory facilities, more preparation of heterocyclic group of compounds may be incorporated by teacher).

10. Biochemistry

L	T	P	Cr
3	1	2	6

Carbohydrates: (8 classes of 60 minutes duration each)

Biological importance of carbohydrates, Metabolism, Cellular currency of energy (ATP), Glycolysis, Alcoholic and Lactic acid fermentations, Krebs cycle.

Proteins: (8 classes of 60 minutes duration each)

Classification, biological importance; Primary, secondary and tertiary structures of proteins: α-helix and β- pleated sheets, Denaturation of proteins.

Enzymes: (8 classes of 60 minutes duration each)

Nomenclature, Characteristics (mention of Ribozymes), Classification; Active site, Mechanism of enzyme action, Stereospecificity of enzymes,Coenzymes and cofactors, Enzyme inhibitors, Biocatalysis in Green Chemistry" and Chemical Industry

Lipids: (8 classes of 60 minutes duration each)

Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications.

Structure of DNA/RNA: (8 classes of 60 minutes duration each)

Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Gene therapy.

Recommended Books/References:

1. Berg, J.M., Tymoczko, J.L. and Stryer, L. (2006) Biochemistry. VI the Edition. W.H. Freeman and Co.

2. Nelson, D. L., Cox, M. M. and Lehninger, A. L. (2009) principles of Biochemistry.IV Edition. W.H. Freeman and Co.

3. Murray, R.K., Granner, D.K., Mayes, P.A. and Rodwell, V.W. (2009) Harper's Illustrated Biochemistry. XXVIII edition. Lange medical Books/ McGraw-Hill

(The above course structure/number of classes are suggestive. Faculty/academic bodies may incorporate revision/may incorporate text and reference books as per need).

Suggested Practical in Biochemistry

1. Quantitative estimation of protein using Lowry's method. Determine the concentration of the unknown sample.

2. Action of salivary amylase at optimum conditions

3. Effect of pH on the action of salivary amylase

4. Effect of temperature on salivary amylase

5. Effect of inhibitor on salivary amylase

6. Study of the activity of Trypsin using fresh tissue extracts.

7. Effect of temperature, organic solvents, on semi-permeable membrane.

8. Isolation of Genomic DNA from E Coli

(The above course structure/number of classes are suggestive. Faculty/academic bodies may incorporate revision/may incorporate text and reference books as per need).

11. Organometallic and Bioinorganic Chemistry

L	T	P	Cr
3	1	2	6

Chemistry of 3d metals: Oxidation states displayed by Cr, Fe, Co, Ni and Co. A study of the following compounds (including preparation and important properties); Peroxo compounds of Cr, $K_2Cr_2O_7$, $KMnO_4$, $K_4[Fe(CN)_6]$, sodium nitroprusside, $[Co(NH_3)_6]Cl_3$, $Na_3[Co(NO_2)_6]$.

Organometallic Compounds

Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. pi-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding.

Zeise's salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls.

Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium.

Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene.

Definition and Classification with appropriate examples based on nature of metal-carbon bond (ionic, s, p and multicentre bonds). Structures of methyl lithium, Zeiss salt and ferrocene. EAN rule as applied to carbonyls. Preparation, structure, bonding and properties of mononuclear and polynuclear carbonyls of 3d metals. p-acceptor behaviour of carbon monoxide. Synergic effects (VB approach)- (MO diagram of CO can be referred to for synergic effect to IR frequencies). Organometallic compounds of Mg and Li – Use in synthesis of organic compounds.

Bioinorganic chemistry

A brief introduction to bio-inorganic chemistry. Role of metal ions present in biological systems with special reference to Na^+, K^+ and Mg^{2+} ions: Na/K pump; Role of Mg^{2+} ions in energy production and chlorophyll. Role of Ca^{2+} in blood clotting, stabilization of protein structures and structural role (bones).

Recommended books/reference books

1.Lippard, S.J. & Berg, J.M. *Principles of Bioinorganic Chemistry* Panima Publishing Company 1994.

2. Cotton, F.A. & Wilkinson, G, *Advanced Inorganic Chemistry* Wiley-VCH, 1999

3. Basolo, F, and Pearson, R.C. *Mechanisms of Inorganic Chemistry*, John Wiley & Sons, NY, 1967.

4.Greenwood, N.N. & Earnshaw A. *Chemistry of the Elements*, Butterworth-Heinemann, 1997

List of Laboratory experiments

(necessary infrastructure may be developed and adequate precaution should be maintained to conduct such experiments; instructor may demonstate the experiment to students)

1.Rection of metal with halide – preparation of Grignard reagent. (only demonstration purpose)

2. Grignard preparation of dye (malachite green (using methylbenoate)/crystal violet (using diethylcarbonate) (starting material as p-bromo N, N-dimethyl aniline) (only demonstration purpose)

3. Preparation of various Schiff base-metal complexes and their identification using spectroscopy.

4. Preparation of any two of the following complexes and measurement of their conductivity measurement:

a. tetraamminecarbonatocobalt (III) nitrate

b. tetraamminecopper (II) sulphate

c. potassium trioxalatoferrate (III) trihydrate

Recommended books/reference books

1.Synthesis of organometallic compounds: A practical guide, S. Komiya, Wiley.

2. A.I. Vogel: Qualitative Inorganic Analysis, Prentice Hall, 7th Edn.

3. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook of Practical Organic Chemistry*, Prentice-Hall,

12. Introduction to Nanochemistry & Applications

L	T	P	Cr
3	1	2	6

Unit-I: Introduction to nanoscience, nanostructure and nanotechnology (basic idea), Overview of nanostructures and nano-materials, classification, (cluster, colloid, nanoparticles, and nanostructures -Spheroid, Wire, Rod, Tube, and Quantum Dot); Calculation of percentage of surface atom and surface to volume ratio of spherical, wire, rod, and disc shapes nanoparticles.

Unit-II: Size dependent properties of nanomaterials (basic idea with few examples only): Quantum confinement, Electrical, Optical (Surface Plasmon resonance), variation in colors (Blue shift & Red shift), Magnetic, thermal and catalytic properties.

Unit-III: Synthesis of Nanomaterials: Brief introduction about Top-down and Bottom-up approaches & self-assembly techniques of nanoparticles synthesis, Solvothermal process, Examples of preparation of gold and silver metallic nanoparticles, self-assembled nanostructures-controlof nanoarchitecture-one dimensional control. Carbon nanotubes and inorganic nanowires.

Unit-IV: Material characterization techniques (basic idea of use of following instruments in nanomaterial characterization need to be emphasized): Electron microscopic technique, diffraction technique, photoelectron spectroscopy, zeta-potential measurement; Examples of use of nanomaterials in environmental remediation and biology (few practical examples of use of materials can be discussed).

Recommended Books/References books:

1.C. N. R. Rao, A. Muller, A. K. Cheetam, The Chemistry of Nanomaterials: Synthesis, Properties and Applications, Willey-VCH Verlag, Germany, 2005.

2.G. Cao, Nanostructures and Nanomaterials: Synthesis, Properties and Appications, Imperial College Press, London, 2004

3.R. W. Kelsall, I. W. Hameley, M. Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, England, 2005

4.Charles P. Poole and Frank J Owens, *Introduction to nano technology*, Wiley Interscience, 2003.

5. Pradeep, T., A text of book of nanoscience and nanotechnology, Tata McGraw Hill Education Pvt. Ltd., New Delhi, 2012.

List of Laboratory Experiments suggested:

1.Synthesis of ZnO nanoparticles.
2. Preparation of Silver nanoparticles.
(diverse nanoparticles can be prepared by various routes)
3.verfification of Beer-Lambert law using nano-particles (above prepared nano-particles may be used for the study).
(Depending upon the availability of infrastructure facilities, instructor may encourage the students to prepare bimetallic nano-particles, etc. and characterized them, study their various properties like magnetism, adsorption, etc.)

Recommended/Ref. Books:

1.Pradeep T., A text book of nanoscience and nanotechnology, Tata McGraw Hill Education Pvt. Ltd., New Delhi, 2012 edition.

GENERIC ELECTIVE COURSES

Generic elective courses are both theory and practical based. Both Honours and Pass students can chose the course as outlined in the pattern of modeled credit distribution. Some of the courses are based largely on practical. These courses shall have the following credit pattern.

L	T	P	Cr
3	1	2	6

1. Mathematical Methods in Chemistry

L	T	P	Cr
3	1	2	6

Fundamentals of mathematics: (10 classes of 60 minutes duration each)

Mathematical functions, polynomial expressions, logarithms, exponential function, units of a measurement, inter-conversion of units, constants and variables, equation of a straight line, plotting graphs, data representation, pi-charts, histogram.

Uncertainty in experimental techniques: Displaying uncertainties and measurements in chemistry, decimal places, significant figures, combining quantities.

Uncertainties in measurement: types of uncertainties, combining uncertainties. Use of statistical tools, Data reduction and the propagation of errors, binomial, Poisson and Gaussian distributions, Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression).

Algebraic operations on real scalar variables, Roots of quadratic equations analytically and iteratively, Numerical methods of finding roots (Newton-Raphson, binary –bisection).

Mathematical series: (10 classes of 60 minutes duration each)

Power series, Maclaurin, Taylor series, convergence (e.g. pressure virial equation of state, colligative properties). Pythagoras theorem in three dimensions. Trigonometric functions, identities.

Differential calculus: (10 classes of 60 minutes duration each)

The tangent line and the derivative of a function, numerical differentiation, differentials of higher order derivatives, discontinuities, stationary points, maximum-minimum problems, inflexion points, limiting values of functions: L'Hopital's rule, combining limits.

Calculus of several variables*:* Functions, change of variables, total differential, chain rule, partial differentiation, Euler's theorem, exact and inexact differentials (applications tin the domains of thermodynamics, surface chemistry), line/surface-integrals.

Integral calculus: (10 classes of 60 minutes duration each)

Integration, odd-even functions, indefinite integrals, standard integrals, methods of integration (by parts, substitution, partial fractions and others. Examples from kinetics, thermodynamics, nuclear chemistry and surface chemistry, numerical integration (Trapezoidal and Simpson rules, e.g. entropy/enthalpy change from heat capacity data), probability distributions and mean values. Tri-gonometric functions (applications in chemistry need to be emphasized throughout)

Recommended Books/References:

1 Chemical Maths Book, E. Steriner, Oxford University Press (1996).

2 Maths for Chemists, Vols 1 and 2 M. C. R. Cockett and G. Dogget, Royal Society of Chemistry, Cambridge (2003).

(The above course structure, number of classes and recommended books/references are suggestive. Faculty/academic bodies may incorporate revision as per need).

(PRACTICALS/COMPUTATIONAL TOOL WORKS NEED TO BE DESIGNED BY FACUTLIES BASED ON THE AVAILABLE FACILITIES)

2. Life Science/Biology-I

L	T	P	Cr
3	1	2	6

Cell and Cellular Processes: (14 classes of 60 minutes)

The Cell Theory; Prokaryotic and eukaryotic cells; Cell size and shape; Eukaryotic Cell components

Cell Organelles

Mitochondria: Structure, marker enzymes, composition; mitochondrial biogenesis; Semiautonomous organelle; Symbiont hypothesis; Proteins synthesized within mitochondria; mitochondrial DNA

Chloroplast: Structure, marker enzymes, composition; semiautonomous nature, chloroplast DNA

ER, Golgi body & Lysosomes: Structures and roles. Signal peptide hypothesis, N-linked glycosylation, Role of golgi in O-linked glycosylation. Cell secretion, Lysosome formation.

Peroxisomes and Glyoxisomes: Structures, composition, functions in animals and plants and biogenesis.

Nucleus (10 classes of 60 minutes duration each)

Nuclear Envelope- structure of nuclear pore complex; chromatin; molecular organization, DNA packaging in eukaryotes, euchromatin and heterochromatin, nucleolus and ribosome

The functions of membranes; Models of membrane structure; The fluidity of membranes; Membrane proteins and their functions; Carbohydrates in the membrane; Faces of the membranes; Selective permeability of the membranes; Cell wall

Cell Cycle: (6 classes of 60 minutes duration each)

Role of Cell division; Overview of Cell cycle; Molecular controls; Meiosis Interphase, Mitosis and Meiosis.

Instrumentation techniques: (10 classes 60 minutes duration each)

Principles of microscopy; Light Microscope; Phase contrast microscopy; Fluorescence microscopy; Confocal microscopy; Sample Preparation for light microscopy; Introduction to Electron microscopy (EM)- Scanning EM and sample analysis with examples.

Recommended books/References:

1. Campbell, N.A. and Reece, J. B. Biology (Eighth edition) Pearson Benjamin Cummings, San Francisco, (2008).

2. Raven, P.H *et al* Biology, Seventh edition Tata McGraw Hill, New Delhi (2006).

3 Sheeler, P and Bianchi, D.E. Cell and Molecular Biology (Third edition) John Wiley (2006)

(The above course structure, number of classes and recommended books/references are suggestive. Faculty/academic bodies may incorporate revision as per need).

Tutorials/practical for Biology (preferably any six from the following list)

1. Study of prokaryotic cells (bacteria), viruses, eukaryotic cells using microscope.
2. Study of the photomicrographs of cell organelles
3. To study the structure of plant cell through temporary mounts.
4. To study the structure of animal cells by temporary mounts-squamous epithelial cell and nerve cell.
5. Preparation of temporary mounts of striated muscle fiber
6. To prepare temporary stained preparation of mitochondria from striated muscle cells/ cheek epithelial cells using vital stain Janus green.
7. To prepare temporary stained squash from root tips of *Allium cepa* and to study the various stages of mitosis.
8. Study the effect of temperature, organic solvent on semi permeable membrane.
9. Demonstration of dialysis of starch and simple sugar.
10. Study of plasmolysis and deplasmolysis on *Rhoeo* leaf.
11. Measure the cell size (either length or breadth/diameter) by micrometry.
12. Study the structure of nuclear pore complex by photograph (from Gerald Karp)

3. Physics-I

L	T	P	Cr
3	1	2	6

Mathematical Physics: (8 classes of 60 minutes duration each)

Scalar and vector products, polar and axial vectors, triple and quadruple products.

Vector calculus:

Scalar and vector fields, differentiation of a vector, gradient, divergence, curl and O operations and their meaning, idea of line, surface and volume integrals, Gauss and Stokes' theorem.

Classical Mechanics: (18 classes of 60 minutes duration each)

Particle dynamics: Newton's laws of motion, conservation of linear momentum, center of mass, conservative forces, work energy theorem, particle collision.

Rotational kinematics and dynamics: Rotational motion, forces and pseudo forces, torque and angular momentum, kinetic energy of rotation, rigid body rotation dynamics, moment of inertia, conservation of angular momentum, comparison of linear and angular momentum, motion of a top.

Oscillations: Linearity and superposition principle, free oscillation with one and two degrees of freedom, simple pendulum, combination of two simple harmonic motions. Lissajous figures, free and damped vibrations, forced vibrations and resonance, Q factor; wave equation, travelling and standing waves, superposition of waves, phase and group velocity.

Wave optics: (14 classes of 60 minutes duration each)

Interference, division of amplitudes, Young's double split, Fresnel's biprism, interference in thin films and wedged shaped films. Fresnel diffraction: Diffraction at a single slit and a circular aperture, diffraction at a double split, plane transmission grating, resolving power of a telescope and a microscope, resolving and dispersive power of a plane diffraction grating. Polarization: Polarization by reflection and refraction, Brewster's law, double refraction, nicol prism, quarter and half-wave plates, Production and analysis of circularly and elliptically polarized light.

Recommended Text books/references:

1. Spiegel, M. R. *Vector Analysis* Schaum Outline Series. McGraw-Hill (1974)

2. Beiser, A. *Concepts of Modern Physics* McGraw-Hill (2002).
3. Resnick, R., Halliday, D. and Krane, K. S. Physics I and II Fifth Ed. John Wiley (2004)
4. Serway, R. A. & Jewett, J. W. *Physics for Scientists and Engineers* Sixth Ed.

(The above course structure, number of classes and recommended books/references are suggestive. Faculty/academic bodies may incorporate revision as per need).

Physics-I– Practicals

(Recommended that physics practical to be carried out from mechanics and optics as per availability of facilities with minimum 3 experiments from each group)

Group-A: Mechanics

1. Determination of spring constant of a spring by (i) static, and (ii) dynamic methods.
2. Study of damped harmonic oscillator- Q factor.
3. Determination of temperature coefficient of resistance using platinum resistance thermometer.
4. Study of thermal couple calibration and inversion temperature.
5. LCR study of resonance Q-factor.
6. Kator's pendulum- Bar pendulum.

Group-B:Optics

7. Determination of wavelength of light by Fresnel's biprism.
8. Determination of wavelength of sodium light by Newton's arrangement.
9. Determination of refractive index of tint glass using a spectrometer.
10. Determination of dispersive power of a glass prism using Cauchy's constant. Also determine the resolving power of a prism.
11. Determination of wavelength of sodium light using a plane transmission grating and resolving power of a diffraction grating.
12. Determination of specific rotation of cane sugar solution using a polarimeter.

4. Mathematics-II

L	T	P	Cr

3	**1**	**2**	**6**

Differential equations: (8 classes of 60 minutes duration each)

Solving differential equations with separable variables, series solution, numerical solutions of differential equations those appear in Newtonian mechanism, harmonic oscillator, Linear differential equations with constant coefficients.

Partial differential equations: separation of variables. **(10 classes of 60 minutes duration each)**

Multiple integrals. Change variables. Vector derivative operators. Multiple integrals involving other coordinate systems (spherical polar). Maximum and minimum of functions of several variables. Stationary points, complex numbers, complex plane, Euler's formula and polar form of complex numbers, complex conjugates, modulus of a complex number.

Operators: (6 classes of 60 minutes duration each)

Operator algebra, linear and Hermitian operators, eigenfunctions and eigenvalues, commutators of operators.

Vectors and coordinate systems: (6 classes of 60 minutes duration each)

Unit vectors (application in solid state), addition and subtraction of vectors, multiplication of vectors. Vector calculus. Vectors and coordinate systems in three dimensions (Cartesian, spherical polar and their inter-conversion), Jacobian.

Determinants and Matrices: (10 classes of 60 minutes each)

Determinant, Matrix algebra, Simultaneous equations: method of substitution and elimination, consistency and independence. Homogeneous linear equations. Simultaneous equations with more than two unknowns, Cramer's rule, matrix inversion, orthogonal and unitary matrices, diagonalization of a matrix.

Recommended Books/references:

McQuarrie D. A. Mathematics for Physical Chemistry Opening Doors, University Science Books (2008).

(The above course structure/number of classes are suggestive. Faculty/academic bodies may incorporate revision/may incorporate text and reference books as per need).

(Suitable Laboratory Practicals may be designed by the faculty of Mathematics/Chemistry based on above course modules and available facilities)

5. Physics-II

L	T	P	Cr
3	1	2	6

Electrostatics and magnetism: (15 classes of 60 minutes duration each)

Electric field, potential due to a charge distribution and due to a dipole, electrical potential energy, flux, Gauss's law, electric field in a dielectric, polarization, energy stored in an electric field. Magnetic field due to a current-carrying conductor, Biot Savart law, magnetic force on a current, Lorentz force, electromagnetic induction, Lenz's law, magnetic properties of matter, para- dia- and ferromagnetism, spinning of a magnetic dipole in an external magnetic field. Modification of Ampere's law, equation of continuity and displacement current, Maxwell's equations, wave equation and its plane wave solution, nature of electromagnetic waves, tranversality and polarization, propagation of electromagnetic plane waves in dielectric media.

Electronics: (15 classes of 60 minutes duration each)

Half-wave, full-wave and bridge rectifiers, ripple factor, rectification efficiency, filters (series in inductor, shunt capacitator, LC and π sections), voltage regulations, load regulation, Zener diode as voltage regulator. Characteristic curves of bipolar transistors, static and dynamic load line, biasing (fixed and self) of transistor circuit, thermal instability of bias, the black box idea of CE, CB and CC transistor circuits as two-port network, small signal active output, hybrid model of a CE transistor circuit, analysis of a small signal amplifier: its voltage and current gains, negative and positive feedback. Barkhausen's criterion for self-sustaining oscillations, LC and phase shift oscillators.

Digital electronics: (10 classes of 60 minutes duration each)

Number systems (binary, BCD, octal and hexadecimal), 1's and 2's complements. Logic gates, AND, OR, NAND, NOR, XOR and NXOR. Boolean algebra (Boolean laws and simple expressions), binary adders, half adder, half subtractor, full adder and full subtractor.

Recommended Text books/References:

1. Griffiths, D. J. *Introduction to Electromagnetism* 3rd Ed. Prentice-Hall (1999).
2. Malvino, A.P. & Leach, D. P. *Digital Principles and Applications*, Tata McGraw- Hill (2008).
3. Ryder, J. D. *Electronic Fundamentals and Applications: Integrated and Discrete Systems.* 5th Ed. Prentice-Hall, Inc. (2007).
4. Floyd, T. L. & Buchla, D. M. *Electronics Fundamentals: Circuits, Devices and Applications* (8th Ed.) Prentice-Hall (2009).

(The above course structure/number of classes are suggestive. Faculty/academic bodies may incorporate revision/may incorporate text and reference books as per need).

Physics Practical

1. Ballistic Galvanometer: resistance, current sensitivity, charge sensitivity, and critical damping resistance of the galvanometer.
2. Determination of high resistance by leakage method.
3. Determination of mutual inductance by Ballistic Galvanometer.
4. Operations and measurements by Cathode Ray Oscilloscope (CRO). Calibration of DC and AC voltages, frequency and phase measurements of a signal.
5. Study of transistor characteristics (CB, CE, CC configurations).
6. Study of power supply (rectification factor, voltage and load regulation for C, L, CL and π filters).
7. Study of basic RC coupled amplifier (frequency response and band width).
8. Self-inductance measurement by Owen's bridge.
9. Measurement of magnetic field by search coil.
10. To verify experimentally OR, NAD, NOT, NOR, NAND gates.

(The above list of experiments are suggestive. Faculty/academic bodies may incorporate revision in the list of experiments depending upon experimental facilities available/may incorporate text and reference books as per need).

ABILITY ENHANCEMENT COURSES

These courses have the following credit pattern. For theory papers:

L	T/P	Cr
3	1	4

1. English for communication

L	T	P	Cr
3	1	0	4

Communication: Language and communication, differences between speech and writing, distinct features of speech, distinct features of writing.

Writing Skills; Selection of topic, thesis statement, developing the thesis; introductory, developmental, transitional and concluding paragraphs, linguistic unity, coherence and cohesion, descriptive, narrative, expository and argumentative writing.

Technical Writing: Scientific and technical subjects; formal and informal writings; formal writings/reports, handbooks, manuals, letters, memorandum, notices, agenda, minutes; common errors to be avoided.

(The above course is suggestive. However, the course teacher/academic bodies may incorporate changes as per the need with incorporation of appropriate text books, reference materials).

2. Intellectual Property Rights

L	T	P	Cr
3	1	0	4

Learning outcomes

On completion of this course, the students will be able to:

- Understand the concept of IPR
- Differentiate between various agreements of IPR
- Compare copyrights, patents and Geographical Indicators
- Examine various legal issues related to IPR
- Relate to various cyber issues concerning IPR

Keywords:

Copyright act, IPR and WTO, Patents, Bioprospecting, Biopiracy, Database

Unit I: Introduction to Intellectual Property Right (IPR) 7 lectures

Copyright Act and IPR, Economic importance. IPR in India and world: Genesis and scope, some important examples. IPR and WTO (TRIPS, WIPO). Objectives, Rights, Patent Act 1970 and its amendments.

Unit II: Patents, Copyrights and Trademarks 7 lectures

Procedure of obtaining patents, working of patents. Infringement of patents, Copyrights: work protected under copyright laws, Rights, Transfer of Copyright, Infringement. Trademarks: Objectives of trademarks, Types, Rights, Protection of goodwill, Infringement, Passing off, Defenses, Domain name.

Unit III: Protection of Traditional Knowledge, Industrial Designs and Plant Varieties 7 lectures

Objective, Concept of Traditional Knowledge, Holders, Issues concerning, Bioprospecting and Bio-piracy, Alternative ways, Protectability, need for a Sui-Generis regime, Traditional Knowledge on the International Arena, at WTO, at National level, Plant varieties protection in India. Rights of farmers, National gene bank, Benefit sharing. Protection of Plant Varieties and Farmers' Rights Act, 2001.

Unit IV: Information Technology Related I P R 7 lectures

Computer Software and Intellectual Property, Database and Data Protection, Protection of Semiconductor chips, Domain Name Protection. Patenting Biotech Inventions: Objective, Applications, Concept of Novelty, Concept of inventive step, Microorganisms, and Moral Issues in Patenting Biotechnological inventions.

Practical:

There are no experimental lab based Practical. However, the students are expected to prepare some project report based on the Success stories of Traditional Patents secured by India. Likewise, prepare a database for Indian products wherein is issue is still under consideration of the competent authorities. Prepare the dos and don’ts on Patents for Botanists

Suggested Readings

1. N.S. Gopalakrishnan and T.G. Agitha, (2009) Principles of Intellectual Property Eastern Book Company, Lucknow.
2. David Kitchin QC , David Llewelyn , James Mellor , Richard Meade , Thomas Moody-Stuart,and D. Keeling, Robin Jacob (2005). Kerly’s Law of Trade Marks and Trade Names (14th Edition) Thomson, Sweet & Maxweel.
3. Ajit Parulekar and Sarita D’ Souza, (2006) Indian Patents Law – Legal & Business Implications; Macmillan India Ltd.
4. B.L.Wadehra (2000) Law Relating to Patents, Trade Marks, Copyright, Designs & Geographical Indications; Universal law Publishing Pvt. Ltd., India.
5. P. Narayanan (2010) Law of Copyright and Industrial Designs; Eastern law House, Delhi.

3. History of Indian Science

L	T	P	Cr
3	1	0	4

Learning outcomes

On completion of this course, the students will be able to:

- Develop understanding of various branches of science during different eras
- Analyze the role played by different Indian organizations in science
- Appraise the contribution of different Indian Scientists in science

Keywords:

Astronomy, Ancient India, Colonial India, Mordern India, Agricultural techniques, Green revolution

Unit I: Science in Ancient and Medieval India 8 lectures

History of development in astronomy, mathematics, engineering and medicine subjects in Ancient India, Use of copper, bronze and iron in Ancient India, The geography in literature of Ancient India. Influence of the Islamic world and Europe on developments in the fields of mathematics, chemistry, astronomy and medicine, innovations in the field of agriculture-new crop introduced new techniques of irrigation.

Unit II: Indian Science in before and after Independence 7 lectures

Introduction of different surveyors, botanists and doctors as early scientist in Colonial India, Indian perception and adoption for new scientific knowledge in Modern India, Establishment of premier research organizations like CSIR, DRDO and ICAR and ICMR, Establishment of Atomic Energy Commission, Launching of the space satellites, Botanical survey of India.

Unit III: Prominent Indian scientists 8 lectures

Eminent scholars in mathematics and astronomy: Baudhayana, Aryabhtatta, Brahmgupta, Bhaskaracharya, Varahamihira, and Nagarjuna, Medical science of Ancient India (Ayurveda and Yoga): Susruta, Charak. Scientists of Modern India: Srinivas Ramanujan, C.V. Raman, Jagdish Chandra Bose, Homi Jehangir Bhabha and Vikram Sarabhai.

Unit IV: Prominent research in Plant Sciences in Republic of India

7 lectures

History of plant tissue culture from India, Green revolution in India: causes, details, and outcomes. First gene cloning in plants, First genome sequencing from India. Premier Plant Research institutes and scientists in India, GM Mustard. Allelopathy Plant research in India

Practical:

There are no experimental lab based Practical. However, the students are expected to prepare some term paper reports on the Life and works of some noted Indian Scientists especially the Botanists. Likewise, students need to prepare and organize some discussion on the ancient and medieval science in India and trace the reasons of inadequate visibility in the world. Prepare term papers on GM Crops, the controversies and procedure for approval. Prepare term papers on the significance of Allelopathic research from India

Suggested Readings

1. Kuppuram G (1990) History of Science and Technology in India, South Asia Books.
2. Handa O. C. (2014) Reflections on the history of Indian Science and Technology, Pentagon Press.
3. Basu A (2006) Chemical Science in Colonial India: The Science in Social History, K.P. Bagchi & Co.
4. Habib I, (2016.)A people's history of India 20: Technology in Medieval India, 5th Edition, Tulika Books.
5. A. Rahman et al (1982) Science and Technology in Medieval India – A Bibliography of Source Materials in Sanskrit, Arabic and Persian, New Delhi: Indian National Science Academy.
6. B. V. Subbarayappa & K. V. Sarma (1985), Indian Astronomy -– A Source Book, Bombay.
7. Srinivasan S, Ranganathan S (2013) Minerals and Metals heritage of India, National Institute of Advanced Studies.
8. Srinivasiengar C N, (1967) The History of Ancient Indian Mathematics, World Press Private Ltd. Calcutta.
9. Bhardwaj H C (2000) Metallurgy in Indian Archaeology. Tara Book Agency

4. Good Laboratory Practices (largely Practical based)

L	T/P	P	Cr
3	1	0	4

Learning outcomes

After completing this course, the learner will be able to:

- Apply practical skills in science courses with the understanding of general laboratory practices
- Use various micro techniques used in chemistry
- Apply various techniques to study chemical compounds, salts
- Explore various research issues and their solutions

Keywords:

Laboratory calculations, calibration procedures, use of glasswares, safety aspects in preparation

Unit I: General Laboratory Practices

Common calculations in chemistry laboratories. Understanding the details on the label of reagent bottles. Preparation of solutions. Molarity and normality of common acids and bases. Dilutions. Percentage solutions. Molar, molal and normal solutions. Technique of handling micropipettes; Knowledge about common toxic chemicals and safety measures in their handling.

Unit II: Instrument-Techniques and laboratory preparation procedure.

Use of micropipette, analytical balances, pH meter, conductivity meter, rotary evaporator, potentiometer. Use of purified water in lab experiments, Cleaning and drying of glasswares, Perpartion of crystals from given salt. Preparation of Dyes, Demonstraton of preparation of material using Sol-gel procedure.

Suggested Readings

1. Seiler, J.P. (2005). Good Laboratory Practices: the why and how. Springer-Verlag Berlin and Heidelberg GmbH & Co. K; 2nd ed.
2. Garner, W.Y., Barge M.S., Ussary. P.J. (1992). Good Laboratory Practice Standards: Application for field and Laboratory studies. Wiley VCH.

5. Introduction to Forensic Science and technology

L	T/P	P	Cr
3	1	0	4

Scope of forensic science, Evidences in criminal law (act, case studies), Physical evidences (identification, collection and preservation of sample, physical properties of sample material, use of physical evidences in criminal proceedings), biological evidences (drugs, effects, identification, serology of blood, semen, saliva, DNA evidence, use of biological evidence in criminal proceedings), trace evidences (finger print, blood stream, hair, firearms, fibers, paints, etc), basic techniques of chemical analysis (FTIR, Mass spectroscopy, HPLC and GC with example of analysis). Admissible and non-admissible scientific evidence in legal system, Principle and limitation of DNA finger printing.

Recommended Books/references:

1.B.B. Nanda and R.K. Tiwari, Forensic Science in India: A Vision for the Twenty First Century, Select Publishers, New Delhi (2001).

2. M.K. Bhasin and S. Nath, Role of Forensic Science in the New Millennium, University of Delhi, Delhi (2002).

3. S.H. James and J.J. Nordby, Forensic Science: An Introduction to Scientific and Investigative Techniques, 2nd Edition, CRC Press, Boca Raton (2005)

4.W.J. Tilstone, M.L. Hastrup and C. Hald, Fisher's Techniques of Crime Scene Investigation, CRC Press, Boca Raton (2013).

6. Renewable Energies (solar and biogas)

L	T/P	P	Cr
3	1	0	4

Introduction to renewable energy sources – solar, wind, small hydro, biomass, geothermal and ocean energy, energy flow in ecosystem Solar Energy Resources Solar radiation: Spectrum of EM radiation, sun structure and characteristics, extraterrestrial radiation, solar constant, air mass, beam, diffused and total solar radiation, spectral distribution

Measurement of solar radiation Instruments: sunshine recorder, Pyranometer, Pyrheliometer, Albedometer. Radiation measurement stations in India (NIWE, IMD etc.), solar radiation data, graphs, Meteonorm and NASA-SSE databases Hands-on measurement of beam, diffuse and total radiation

Solar mapping using satellite data, Typical Meteorological Year

Models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components

Basics Biomass resources: plant derived, residues, aquatic and marine biomass, various wastes, photosynthesis. Biomass resource assessment Estimation of woody biomass, non woody biomass and wastes, ASTM standards

Bulk chemical properties Moisture content, proximate and ultimate analyses, calorific value, waste water analysis for solids

Chemical composition of biomass Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation, protein content in biomass, extractable, COD.

Structural properties Physical structure, particle size and size distribution, permeability. Physical properties: Bulk density, angle of repose, thermal analysis (thermogravimetric, differential thermal and differential scanning calorimetry).Properties of microbial biomass: Protein estimation, flocculating ability, relative hydrophobicity of sludge, sludge volume index.

7. Chemoinformatics

L	T/P	P	Cr
3	1	0	4

Introduction to Chemoinformatics: History, Prospects of chemoinformatics, Molecular Modelling and Structure elucidation.

Representation of molecules and chemical reactions: Nomenclature, Different types of notations, SMILES coding, Matrix representations, Structure of Molfiles and Sdfiles, Libraries and toolkits, Different electronic effects, Reaction classification.

Searching chemical structures: Full structure search, sub-structure search, basic ideas, similarity search, three dimensional search methods, basics of computation of physical and chemical data and structure descriptors, data visualization.

Applications: Prediction of Properties of Compounds; Linear Free Energy Relations; Quantitative Structure-Property Relations; Descriptor Analysis; Model Building; Modeling.

Toxicity; Structure-Spectra correlations; Prediction of NMR, IR and Mass spectra; Computer Assisted Structure elucidations; Computer Assisted Synthesis Design, Introduction to drug design; Target Identification and Validation; Lead Finding and Optimization; Analysis of HTS data; Virtual Screening; Design of Combinatorial Libraries; Ligand and structure based drug design; Applications in Drug Design.

Recommended Books/references:

1. Andrew R. Leach and Valerie, J. Gillet (2007) *An introduction to Chemoinformatics.* Springer: The Netherlands.

2. Gasteiger, J. and Engel, T. (2003) *Chemoinformatics: A text-book.* Wiley-VCH.

3. Gupta, S. P. (2011) *QSAR & Molecular Modeling.* Anamaya Pub.: New Delhi.

8. Water remediation and conservation studies

L	T	P	Cr
3	1	0	4

Sources of water pollutants, pollutants, Industrial and human contribution, WHO recommendation about potable water, current scenario of drinking water quality, chemistry of toxicants like arsenic, fluoride, chromium, lead and mercury, cause and effects of water pollution, remediation, techniques involved such as adsorption, coagulation-filtration, Nalgonada techniques, reverse osmosis, activated charcoal detoxification, applications of non-toxic oxides and mixed oxides, regeneration and recycling, mechanisms of detoxification, bio-remediation, need of green chemistry, future scope.

Introduction to water conservation and erosion of soil, forms of water erosion, factors affecting water erosion, types of water erosion, mechanics of water erosion control, agronomical measures of water erosion control, Terraces for water erosion control:
Modeling of watershed processes, Case study of water-shed modeling for water conservation and water quality.

Recommended Books/references:

1. Cittenden J. C. , Trussell J. R., Hand D. W., Howe K. J., Tchobanoglous G. , Water treatment: Principles and Design MWH publication.
2. De A. K. Environmental Chemistry, Wiley Eastern
3. Clarson D., Dara S. S. A text book of Environmental chemistry and pollution control, S Chand Co. Soil and water analytical method
4. Edzwald J., Water Quality & Treatment: A Handbook on Drinking Water (Water Resources and Environmental Engineering Series)

9. Research Methodology

L	T	P	Cr
2	0	2	4

Learning outcomes:

At the end of the course the students will be able to,

- Understand the concept of research and different types of research in the context of biology
- Develop laboratory experiment related skills.
- Develop competence on data collection and process of scientific documentation
- Analyze the ethical aspects of research
- Evaluate the different methods of scientific writing and reporting

Keywords:

Qualitative, Quantitative, Reproducibility, Scientific methodology, Plagiarism, Scientific misconduct, Ethics in Science

Unit I: Basic Concepts of Research **12 lectures**

Research-definition and types of research (Descriptive vs analytical; applied vs fundamental; quantitative vs. qualitative; conceptual vs empirical). Research methods vs methodology. Literature-review and its consolidation; Library research; field research; laboratory research.

Unit II: Data Collection and Documentation of Observations **12 lectures**

Maintaining a laboratory record; Tabulation and generation of graphs. Imaging of tissue specimens and application of scale bars. The art of field photography.

Unit III: Overview of Application to Chemistry related problems **10 lectures**

Key chemistry research areas, chemoinfomatics.

Unit IV: Ethics and Good Practical's and Art of Scientific Writing

11 lectures

Authors, acknowledgements, reproducibility, plagiarism, Numbers, units, abbreviations and nomenclature used in scientific writing. Writing references. Power-point presentation. Poster presentation. Scientific writing and ethics, Introduction to copyright-academic misconduct/plagiarism.

Practical

1. Experiments based on chemical calculations.
2. Lab computational experiments.
3. Poster presentation on defined topics.
4. Technical writing on topics assigned.
5. Identification of different type of research in day by day life
6. Curation of relevant scientific literature from Google Scholar
7. Demonstration for checking of plagiarism using recommended software
8. Technical writing on topics assigned.

(More Practical may be added depending on the available facilities)

Suggested Readings

1. Dawson, C. (2002). Practical research methods. UBS Publishers, New Delhi.

10. Chemistry in Everyday life

L	T	P	Cr
2	0	2	4

Respiration and energy production in human body

Respiration, Respiratory enzymes, brief outline of hemoglobin and myoglobin, oxygen transport mechanism in body, co-operativity, Respiration in lower animals, hemocyanine, hemerythrine. Energy production in body, ATP; enzyme responsible for food digestion, mechanism of food digestion, active site of cytochrome c-oxidase.

Chemical aspects of some common health hazards

Anemia, sickle cell anemia, leukemia, blood pressure irregulation, blood sugar, arthritis, carbon monoxide poisoning in mines, cyanide poisoning, fluorosis etc.

Vitamins and minerals:

Need for vitamin in body, types of vitamins, water soluble and fat soluble vitamins, Vitamin B-12, vitamin C (Cyanocobalamine), D, Vitamin K. Role of minerals in body, iodine deficiency and remedy.

Significance of Radical chemistry in living system

Radical production in environment, superoxide and peroxide, health impact, action of radicals, cell mutation, diseases caused by free radical, cancer, radical quencher, anti-oxidants, natural anti-oxidants like vegetables, beverages like tea and coffee, fruits.

Radical destroying enzymes: superoxide dismutase, catalase, peroxidase, mechanism of action.

Chemistry of Materials

Soaps and Detergents – their action, Biofuels – production of biofuels and its utility as alternative fuel source, Fibers: natural fibers, cotton, wool, silk, rayon, artificial fibers, polyamides, acrylic acid, PVC, PVA; Examples of natural biodegradable polymers, cellulose, cellulose acetate, cellophane, soy protein, corn, zein protein, wheat gluten protein, synthetic biodegradable polymers. Use of polymeric materials in daily life.

Recommended Books/references:

1. Kaim W, Bioinorganic Chemistry, Vol 4, Brigitte Scwederski, Wiley, 1994.
2. Crichton R. H. Biological Inorganic Chemistry – An Introduction, Elsevier, 2008.
3. Berg J. M., Tymoczeko J. L., Stryer l. Biochemistry, W. H. Freeman, 2008.
4. Bertini, I., Gray, H. B., Lippard, S. J. and Valentine, J. S. (1994) *Bioinorganic Chemistry.* University Science Books (1994)
5. Lippard S., Berg J. M. Principles of Bioinorganic Chemistry; University Science Books 1994.
6. Polymer science, V. R. Gowariker, N. V.Viswanathan, J. Sreedhar, New Age International.

Suggested Laboratory experiments:

1.Analysis of soaps and detergents.

2. Analysis of Biofuels - flash point, pour point, cloud point

3. Preparation of Nylon6/6,6

4. Testing of adulterant in food, oil and vegetable

5. Vitamin-C preparation.

11.Chemistry of food, nutrition and preservation

L	T/P	P	Cr
3	1	0	4

Learning objective:

1.To know about the basic of human physiological system and food science

2. To learn about the nutrition and its importance

3. To learn about the food preservation and its utility.

Key words: Food, nutrition, preservation.

Unit-1: (10 lecture class)

Basic of human physiological system and food science:

Digestive System: Structure and functions of G.I. tract, Process of digestion and absorption of food, Structure and functions of liver, gallbladder and pancreas.Basic concept on Food, Nutrition and Nutrients (Nutrition, Malnutrition and Health: Scope of Nutrition.), Classification of Food, Classification of Nutrients.

Unit-II (10 lecture class)

Nutrition: Dietary fibers (composition, properties and Minerals and trace elements (biochemical and physiological role, bioavailability and requirement with examples), Vitamines (examples, biochemical and physiological requirments, deficiency and excesses), Water (requirement, water balance), basic idea about community nutrition (objective, importance of various programmes).

Unit-III (10 lecture class)

Food preservation:

Food preservation: definition, objectives and principles of food preservation. Different methods of food preservation. Preserved Products: Jam, Jelly, Marmalade, Sauces, Pickles, Squashes, Syrups-types, composition and manufacture, selection, cost, storage, uses and nutritional aspects, Food Standards : ISI, Agmark, FPO, MPO, PFA, FSSAI.

Practical:

Identification of Mono, Di and polysaccharides, Identification of Proteins, Identification of glycerol., Determination of moisture content in food, ash content and determination of calcium, iron, vitamin-C.

Comparison with norms and interpretation of the nutritional assessment data and its significance. Weight for age, height for age, weight for height, body Mass Index (BMI) Waist - Hip Ratio (WHR). Skin fold thickness.

Quantitative estimation of Sugars (Glucose, lactose, starch), Estimation of acid value, iodine value, Saponification value of fats, Estimation of blood Glucose, Estimation of serum cholesterol

Reference/suggested books

1. SrilakshmiB(2017): Nutrition Science,6th Multicolour Ed. New Age International (P) Ltd.

2. RodayS(2012): Food Science and Nutrition, 2nd Ed. Oxford University Press.

3. Mann J and TruswellS(2017) : Essentials of Human Nutrition, 5th Ed. Oxford University Press.

4. Wilson K and Walker J(2000): Principles and Techniques of Practical Biochemistry, 5th Ed. Oxford University Press.

5. Sadasivan S and ManikamK(2007): Biochemical Methods, 3rd Ed. New Age International (P) Ltd.

6. Oser B L(1965). Hawk's Physiological Chemistry, 14th Ed. McGraw-Hill Book

7. GopalanC , Rama Sastri BV and Balasubramanian SC(2016): Nutritive value of Indian Foods, Indian Council of Medical Research.

8. Subalakshmi, G and Udipi, SA(2006):Food processing and preservation, 1st Ed. New Age International (P)Ltd.

9..SrilakshmiB(2018): Food Science, 7th Colour Ed. New Age International (P) Lt

10. Potter NN and Hotchkiss JH(1999): Food science,5th Ed , Spinger.

SKILL ENHANCEMENT COURSES

A number of courses has been enlisted. These courses have the following credit pattern. For theory based papers:

L	T	P	Cr
2	0	0	2

For practical based papers:

L	T	P	Cr
0	0	2	2

1. Skill Enhancement Course: Personality Development

L	T	P	Cr
2	0	0	2

Learning outcomes:

After the completion of this course, the learner will be able to:

- Develop understanding of the concepts and principles of basic psychological skills
- Apply techniques and methods to enhance productivity and time management
- Develop critical thinking skills
- Organize human resources with improved leadership qualities

Keywords:

Mental heuristics, Mental priming, Checklists, Stress management, Cognitive biases, Leadership qualities

Unit I: Basic Psychology Skills **8 lectures**

Mental Heuristics and Priming, Cialdini's six psychological principles, Charisma and charisma enhancements, facing interviews

Unit II: Productivity and Time Management **7 lectures**

Eisenhower Matrix, Pomodoro Technique, Dealing with Procrastination, Journaling methods, Checklists, to-do lists and scheduling the events

Unit III: Dealing Negativity **7 lectures** Work-life balance, stress management, coping with failures and depression

Unit IV: Critical Thinking and Human resources **8 lectures**

Logical fallacies, Cognitive biases, Mental Models, Critical Thinking. Evaluation and improvement; Leadership qualities.

Suggested Readings

2. Bast, F. (2016). Crux of time management for students. Available at: https://www.ias.ac.in/article/fulltext/reso/021/01/0071-0088
3. Cialdini, R.B. (2001). Influence: The Psychology of Persuasion, Revised Edition. Harper Collius.
4. Green, C.J. (2015). Leadership and soft skills for students: Empowered to succeed in High School, College and beyond. Dog Ear Publishing.
5. Velayudhan, A. and Amudhadevi, N. V. (2012). Personality Development for College Students. LAP Lambert Academic Publishing.

2. Computer Applications in Chemistry

L	T	P	Cr
2	0	0	2

Learning outcomes:

After the completion of this course the learner will be able to:

- Apply the basic operations of spreadsheet applications
- Recognize advanced resources for accessing scholarly literature from internet
- Utilize bibliography management software while typing and downloading citations
- Operate various software resources with advanced functions and its open office substitutes

Keywords:

Spreadsheet, Google search, Subscription, Bibliography, MS office, Image processing

Unit I: Spreadsheet Applications **8 lectures**

Introduction of spreadsheet (MS Excel), application, formulas and functions, performing basic statistics using spreadsheet applications, creating basic graphs using spreadsheet applications, logical (Boolean) operators.

Unit II: Internet Resources **7 lectures**

Advanced Google search operators and Boolean functions, Introduction to Google Scholar and accessing scholarly literature from Internet, Fake News and spotting the fake news, multimedia resources and podcasts, RSS/XML Feeds and feed subscription using a feed reader.

Unit III: Bibliography management **8 lectures**

Introducing a bibliography management software (for e.g. Endnote), Styles and Templates, Changing the bibliography style as per journal format, Citing while typing in the office application, downloading citations from Google Scholar.

Unit IV: Other software resources **7 lectures**

Introduction to advanced functions of MS Word and its Open Office substitutes including tracking changes, inserting page numbers and automatic table of contents, Google Docs and Forms, MS Power point, Microphotography and scale calibration with ImageJ, digital image processing (Paint.net or GIMP).

Suggested Readings

1. User manual and online user manual of respective soft wares for the most updated content
2. Published books are not recommended as versions keep on updating very frequently; therefore, it is not easy to follow.

3. Science Communication and Popularization

L	T	P	Cr
2	0	0	2

Learning outcomes:

After the completion of this course, the learner will be able to:

- Identify the need and role of science communication in human development
- utilize visual media science communication for creating scripts and documentaries
- Contribute in science popularization through internet communication and public sensitization

Keywords:

Print science, Visual media, Internet communication, Blogs, Outreach talks, Public sensitization

Unit I: Print Science Communication **9 lectures**

Need for Science Journalism: Science has potential for breaking news, impact on Human life, impact on technology. Role of science and technology in human development. Framing policies at national and international levels. Writing and communicating popular articles effectively, case studies of celebrated works of science communicators including Cosmos by Carl Sagan, works of Bill Bryson, Richard Dawkins, Richard Feynman, Isaac Asimov, Carl Zimmer and Matt Riddley, importance for communication through regional languages.

Unit II: Visual Media Science Communication **7 lectures**

Science outreach through visual media: Creating science documentaries, creating the outline and expanding, scripts, citing authentic sources, case study: Famous documentaries of Carl Sagan, David Attenborough and Prof. Yashpal

Unit III: Internet Science Communication 7 lectures

Science outreach through internet: Social media, Websites, Blogs, Youtube, Podcast etc.

Unit IV: Science Outreach Talks and Public Sensitization 7 lectures

Tactics for providing a charismatic and effective public talk, use of metaphors, speaking in context, Science outreach for biodiversity conservation sensitization of public

Suggested Readings

1. Selected works of Carl Sagan, works of Bill Bryson, Richard Dawkins, Richard Feynman, Isaac Asimov, Carl Zimmer and Matt Riddley.
2. Gigante, E. Marie (2018). Introducing Science Through Images: Cases of Visual Popularization (Studies in Rhetoric/Communication), University of South Carolina Press.

4. Biofertilizers (Practical based course)

L	T	P	Cr
2	0	0	2

Learning outcomes:

On the completion of this course, the students will be able to;

- Develop their understanding on the concept of bio-fertilizer
- Identify the different forms of biofertilizers and their uses
- Compose the Green manuring and organic fertilizers
- Develop the integrated management for better crop production by using both nitrogenous and phosphate bio fertilizers

Keywords:

Useful microbes, Cyanobacteria, Mycorrhiza, Organic farming, Recycling, Vermicompost

Unit I **9 lectures**

General account about the microbes used as biofertilizer – Rhizobium – isolation, identification, mass multiplication, carrier based inoculants, Actinorrhizal symbiosis. *Azospirillum:* isolation and mass multiplication – carrier based inoculant, associative effect of different microorganisms. *Azotobacter*: classification, characteristics – crop response to *Azotobacter* inoculum, maintenance and mass multiplication.

Unit II **7 lectures**

Cyanobacteria (blue green algae), *Azolla* and *Anabaena azollae* association, nitrogen fixation, factors affecting growth, blue green algae and *Azolla* in rice cultivation.

Unit III **7 lectures**

Mycorrhizal association, types of mycorrhizal association, taxonomy, occurrence and distribution, phosphorus nutrition, growth and yield – colonization of VAM – isolation and inoculum production of VAM, and its influence on growth and yield of crop plants.

Unit IV **7 lectures**

Organic farming – Green manuring and organic fertilizers, Recycling of bio- degradable municipal, agricultural and Industrial wastes – biocompost making methods, types and method of vermicomposting – field Application.

Suggested Readings

1. Dubey, R.C. (2005). A Text book of Biotechnology S.Chand & Co, New Delhi.
2. John Jothi Prakash, E. (2004). Outlines of Plant Biotechnology. Emkay Publication, New Delhi.
3. Kumaresan, V.(2005). Biotechnology, Saras Publications, New Delhi.
4. NIIR Board. (2012). The complete Technology Book on Biofertilizer and organic farming. 2nd Edition. NIIR Project Consultancy Services.
5. Sathe, T.V. (2004) Vermiculture and Organic Farming. Daya publishers.
6. Subba Rao N.S. (2017). Biofertilizers in Agriculture and Forestry. Fourth Edition. Medtech.
7. Vayas,S.C, Vayas, S. and Modi, H.A. (1998). Bio-fertilizers and organic Farming Akta Prakashan, Nadiad.

5. Herbal Technology (Practical based)

L	T	P	Cr
2	0	0	2

Learning outcomes:

On completion of this course the students will be able to;

- Develop their understanding on Herbal Technology
- Define and describe the principle of cultivation of herbal products.
- List the major herbs, their botanical name and chemical constituents.
- Evaluate the drug adulteration through the biological testing
- Formulate the value added processing / storage / quality control for the better use of herbal medicine
- Develop the skills for cultivation of plants and their value added processing / storage / quality control

Keywords:

Herbal medicines, Plant products, Biopesticides, Pharmacognosy, Adulteration, Secondary metabolites

Unit I **7 lectures**

Herbal Technology: Definition and scope; Herbal medicines: history and scope; Traditional systems of medicine, and overview of AYUSH (Traditional Indian Systems of Medicine); Cultivation - harvesting - processing - storage of herbs and herbal products.

Unit II **7 lectures**

Value added plant products: Herbs and herbal products recognized in India; Major herbs used as herbal medicines, nutraceuticals, cosmeticals and biopesticides, their Botanical names, plant parts used, major chemical constituents.

Unit III **8 lectures**

Pharmacognosy - Systematic position, botany of the plant part used and active principles of the following herbs: Tulsi, Ginger, Curcuma, Fenugreek, Indian Gooseberry, *Catharanthus roseus*, *Withania somnifera*, *Centella asiatica*, *Achyranthes aspera*, Kalmegh, Giloe (Tinospora), Saravar. Herbal foods, future of pharmacognosy.

Unit IV **8 lectures**

Analytical pharmacognosy: Morphological and microscopic examination of herbs, Evaluation of drug adulteration - types, methods of drug evaluation - Biological testing of herbal drugs - Phytochemical screening tests for secondary metabolites (alkaloids, flavonoids, steroids, triterpenoids, phenolic compounds). Plant gene banks, Cultivation of Plants and their value added processing / storage / quality control for use in herbal formulations, Introductory knowledge of Tissue culture and Micro propagation. of some medicinal plants (*Withania somnifera*, neem and tulsi),

Suggested Readings

1. Agarwal, P., Shashi, Alok., Fatima, A. and Verma, A. (2013). Current scenario of Herbal Technology worldwide: An overview. *Int J Pharm Sci Res*; 4(11): 4105-17.
2. Arber, Agnes. (1999). Herbal Plants and Drugs. Mangal Deep Publications, Jaipur.
3. Varzakas, T., Zakynthinos, G, and Francis Verpoort, F. (2016). Plant Food Residues as a Source of Nutraceuticals and Functional Foods. Foods 5 : 88.
4. Aburjai, T. and Natsheh, F.M. (2003). Plants Used in Cosmetics. Phytotherapy Research 17 :987-1000.
5. Patri, F. and Silano, V. (2002). Plants in cosmetics: Plants and plant preparations used as ingredients for cosmetic products - Volume 1. ISBN 978-92-871-8474-0, pp 218.
6. AYUSH (www.indianmedicine.nic.in). *About the systems—An overview of Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy*. New Delhi: Department of Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy (AYUSH), Ministry and Family Welfare, Government of India.

7. Evans, W.C. (2009): Trease and Evans PHARMACOGNOSY. 16th Edition, SAUNDERS / Elsevier.

8. Sivarajan, V.V. and India, B. (1994). Ayurvedic Drugs and Their Plant Sources.. *Oxford & IBH Publishing Company*, 1994 - Herbs - 570 pages.

9. Miller, L. and Miller, B. (2017). Ayurveda & Aromatherapy: The Earth Essential Guide to Ancient Wisdom and Modern Healing. *Motilal Banarsidass*,; *Fourth edition* .

10. Kokate, C.K. (2003). Practical Pharmacognosy. Vallabh Prakashan, Pune.

6. Fermentation Science and Technology

L	T	P	Cr
2	0	0	2

Learning outcomes:

After completing this course the learner will be able to;

- Employ the process for maintenance and preservation of microorganisms
- Analyze the various aspects of the fermentation technology and apply for Fermentative production
- Demonstrate proficiency in the experimental techniques for microbial production of enzymes: amylase and protease, bio product recover

Keywords:

Microbial culture, Fermentation, Metabolites, Fermented products, Enzyme production, Bioproduct recovery

Unit I **8 lectures**

Preparation of microbial culture, Preparation and sterilization of fermentation media. Isolation and improvement of industrially important microorganisms.

Unit II **8 lectures**

Maintenance and preservation of microorganisms, Metabolic regulations and overproduction of metabolites. Kinetics of microbial growth and product formation.

Unit III **8 lectures**

Scope and opportunities of fermentation technology. Principles of fermentation: Submerged, solid state, batch, fed-batch and continuous culture. Fermentative production of vinegar, alcohol (ethanol, wine, beer), acids (citric acid and gluconic acid), amino acids (lysine and glutamic acid) and antibiotics (penicillin and streptomycin).

Unit IV **6 lectures**

Microbial production of enzymes: Amylase and Protease. Bioproduct recovery.

Suggested readings

1. Waites M.J. (2008). Industrial Microbiology: An Introduction, 7th Edition, Blackwell Science, London, UK.
2. Prescott S.C., Dunn C.G., Reed G. (1982). Prescott & Dunn's Industrial Microbiology, 4th Edition, AVI Pub. Co., USA.
3. Reed G. (2004). Prescott & Dunn's industrial microbiology, 4th Edition, AVI Pub. Co., USA.
4. JR Casida L.E. (2015). Industrial Microbiology, 3rd Edition, New Age International (P) Limited Publishers, New Delhi, India.
5. Waites M.J., Morgan N.L., Rockey J.S. and Higton G. (2001) Industrial Microbiology: An Introduction. 1st Edition, Blackwell Science, London, UK.
6. Pelczar M.J., Chan E.C.S. and Krieg N.R. (2003) Microbiology. 5th Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi.

7. Environmental impact analysis (Practical based)

L	T	P	Cr
2	0	0	2

Learning outcomes:

After completing this course the learner will be able to;

- Have critical understanding of environmental impact
- Learn important steps of EIA process
- Interpret the environmental appraisal and procedures in India.

Keywords:

Environmental management, Environmental impact assessment, Project proponent, Consultant, Environmental audit, Risk assessment, Legislation

Unit I: Origin and Development **8 lectures**

Purpose and aim, core values and principles, History of EIA development, Environmental Management Plan, Environmental Impact Statement, Scope of EIA in Project planning and Implementation.

Unit II: EIA Process **8 lectures**

Components of EIA, EIA Methodology- Screening, Scoping, Baseline data, Impact Identification, Prediction, Evaluation and Mitigation, Appendices and Forms of Application, Techniques of Assessment-Cost-benefit Analysis, Matrices, Checklist, Overlays, Impact on Environmental component: air, noise, water, land, biological, social and environmental factors. EIA Document.

Unit III: Main participants in EIA Process **7 lectures**

Role of Project proponent, environmental consultant, PCBs, PCCs, public and IAA. Public participation.

Unit IV: Environmental Appraisal and Procedures in India and EIA

7 lectures

Methodology, indicators and mitigation, Environmental Audit of different environmental resources, Risk Analysis, Strategic environmental assessment, ecological impact assessment: legislation.

Practical

1. Prepare a Matrix of every environmental existing resource of your college or your hostel/mohalla or any defined area and evaluate each component using established methods and make audit analysis
2. Prepare a case report of Environmental impact of any area under development

Suggested readings:

1. Kulkarni V and Ramachandra TV, (2006). Environmental Management, Capital Pub. Co. New Delhi.
2. Petts, J. (2005) Handbook of Environmental Impact Assessment- Volume 1 and 2. Blackwell Publishers, UK.
3. Glasson, J. Therivel, R. and Chadwick, (2006) A. Introduction to Environmental Impact Assessment. Routledge, London..
4. Canter, W. L. (1995) Environmental Impact Assessment, McGraw-Hill Science/ Engineering/ Math, New York;
5. Morris, P. and Therivel, R. (1995) Methods of Environmental Impact Assessment, UCL Press, London;
6. Petts, J. (1999) (ed) Handbook of Environmental Impact Assessment, volume 1 and 2, Blackwell Science, Oxford;
7. Therivel, R. and Partidario, M. R. (1996) (eds) The Practice of Strategic Environmental Assessment, Earthscan, London;
8. Vanclay, F. and Bronstein, D. A. (1995) (eds) Environmental and Social Impact Assessment, Wiley & Sons, Chichester

8. Skill Enhancement Course: IT skills for chemists

L	T	P	Cr
2	0	0	2

1. IT Skills for Chemists

Fundamentals, mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, inter-conversion of units, constants and variables, equation of a straight line, plotting graphs.

Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities. Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression). Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms).Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).

Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations). Numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data).

Computer programming:

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

BASIC/FORTRAN programs for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson's rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

Recommended books/References:

1.McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).

2. Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).

3.Steiner, E. The Chemical Maths Book Oxford University Press (1996).

4.Yates, P. Chemical calculations. 2nd Ed. CRC Press (2007).

5.Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.

6. Levie, R. de, How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press (2001) 487 pages.

7.Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985).

8. Venit, S.M. Programming in BASIC: Problem solving with structure and style. Jaico Publishing House: Delhi (1996).

9. Intellectual property right (IPR) and business skills for chemists

L	T	P	Cr
2	0	0	2

Introduction to Intellectual Property:

Historical Perspective, Different Types of IP, Importance of protecting IP.

Copyrights

Introduction, How to obtain, Differences from Patents.

Trade Marks

Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, Trade names, etc. Differences from Designs.

Patents Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Healthcare – balancing promoting innovation with public health, Software patents and their importance for India.

Geographical Indications

Definition, rules for registration, prevention of illegal exploitation, importance to India.

Industrial Designs

Definition, How to obtain, features, International design registration.

Layout design of integrated circuits

Circuit Boards, Integrated Chips, Importance for electronic industry.

Trade Secrets

Introduction, Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection.

Different International agreements

(a) Word Trade Organization (WTO):

(i) General Agreement on Tariffs & Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement (ii) General Agreement on Trade related Services (GATS) (iii) Madrid Protocol (iv) Berne Convention (v) Budapest Treaty

(b) Paris Convention

WIPO and **TRIPS, IPR** and Plant Breeders Rights, IPR and Biodiversity

IP Infringement issue and enforcement – Role of Judiciary, Role of law enforcement agencies – Police, Customs etc. Economic Value of Intellectual Property – Intangible assets and their valuation, Intellectual Property in the Indian Context – Various laws in India Licensing and technology transfer.

Business Basics

Key business concepts: Business plans, market need, project management and routes to market.

Chemistry in Industry

Current challenges and opportunities for the chemistry-using industries, role of chemistry in India and global economies.

Financial aspects

Financial aspects of business with case studies.

Recommended Books/References:

1. Acharya, N.K. Textbook on intellectual property rights, Asia Law House (2001).

2.Guru, M. & Rao, M.B. Understanding Trips: Managing Knowledge in Developing Countries, Sage Publications (2003).

3. Ganguli, P. Intellectual Property Rights: Unleashing the Knowledge Economy, Tata McGraw-Hill (2001).

4. Miller, A.R. & Davis, M.H. Intellectual Property: Patents, Trademarks and Copyright in a Nutshell, West Group Publishers (2000).

5. Watal, J. Intellectual property rights in the WTO and developing countries, Oxford University Press, New Delhi.

10. Analytical Clinical Biochemistry

L	T	P	Cr
2	0	0	2

Structure, properties and functions of carbohydrates, lipids and proteins:

Carbohydrates: Biological importance of carbohydrates, Metabolism, Cellular currency of energy (ATP), Glycolysis, Alcoholic and Lactic acid fermentations, Krebs cycle. Isolation and characterization of polysachharides.

Proteins: Classification, biological importance; Primary and secondary and tertiary structures of proteins: α-helix and β- pleated sheets, Isolation, characterization, denaturation of proteins.

Enzymes: Nomenclature, Characteristics (mention of Ribozymes), Classification; Active site, Mechanism of enzyme action, Stereospecificity of enzymes, Coenzymes and cofactors, Enzyme inhibitors, Introduction to Biocatalysis: Importance in "Green Chemistry" and Chemical Industry.

Lipids: Classification. Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications. Lipoproteins: Properties, functions and biochemical functions of steroid hormones. Biochemistry of peptide hormones.

Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Gene therapy. *Enzymes*: Nomenclature, classification, effect of pH, temperature on enzyme activity, enzyme inhibition.

A diagnostic approach to biochemistry:

Blood: Composition and functions of blood, blood coagulation. Blood collection and preservation of samples. Anaemia, Regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.

Urine: Collection and preservation of samples. 6. Formation of urine. Composition and estimation of constituents of normal and pathological urine.

Recommended books/references:

1. Cooper, T.G. *Tool of Biochemistry*. Wiley-Blackwell (1977).

2. Wilson, K. & Walker, J. *Practical Biochemistry.* Cambridge University Press (2009).

3. Varley, H., Gowenlock, A.H & Bell, M.: *Practical Clinical Biochemistry*, Heinemann, London (1980).

4. Devlin, T.M., *Textbook of Biochemistry with Clinical Correlations*, John Wiley & Sons, 2010.

5. Berg, J.M., Tymoczko, J.L. & Stryer, L. *Biochemistry*, W.H. Freeman, 2002.

6. Talwar, G.P. & Srivastava, M. *Textbook of Biochemistry and Human Biology*, 3rd Ed. PHI Learning.

7. Nelson, D.L. & Cox, M.M. *Lehninger Principles of Biochemistry*, W.H. Freeman, 2013.

8. O. Mikes, R.A. Chalmers: *Laboratory Handbook of Chromatographic Methods*, D. Van Nostrand & Co., 1961.

Analytical Clinical Biochemistry Practical

Identification and estimation of the following:

1. Carbohydrates – qualitative and quantitative.
2. Lipids – qualitative.
5. Determination of cholesterol using Liebermann- Burchard reaction.
6. Proteins – qualitative.
7. Isolation of protein.
8. Determination of protein by the Biuret reaction.
9. Determination of nucleic acids.

(visit to clinical laboratory/medical centre(s))

Recommended Books/References:

1. Cooper, T.G. *Tool of Biochemistry*. Wiley-Blackwell (1977).

2. Wilson, K. & Walker, J. *Practical Biochemistry*. Cambridge University Press (2009).

3. Varley, H., Gowenlock, A.H & Bell, M.: *Practical Clinical Biochemistry*, Heinemann, London (1980).

4. Devlin, T.M., *Textbook of Biochemistry with Clinical Correlations*, John Wiley & Sons, 2010.

5. Berg, J.M., Tymoczko, J.L. & Stryer, L. *Biochemistry*, W.H. Freeman, 2002.

6. Talwar, G.P. & Srivastava, M. *Textbook of Biochemistry and Human Biology*, 3rd Ed. PHI Learning.

7. Nelson, D.L. & Cox, M.M. *Lehninger Principles of Biochemistry*, W.H. Freeman, 2013.

8. O. Mikes, R.A. Chalmers: *Laboratory Handbook of Chromatographic Methods*, D. Van Nostrand & Co., 1961.

11. Mushroom Culture Technology

L	T	P	Cr
2	0	0	2

Learning outcomes:

On completion of this course, the students will be able to:

- Recall various types and categories of mushrooms.
- Demonstrate various types of mushroom cultivating technologies.
- Examine various types of food technologies associated with mushroom industry.
- Value the economic factors associated with mushroom cultivation
- Device new methods and strategies to contribute to mushroom production.

Keywords:

Edible mushrooms, Poisonous mushrooms, Cutivation technology, Mushroom bed, Mushroom unit, Storage and Nutrition

Unit I **7 lectures**

Introduction, History. Nutritional and medicinal value of edible mushrooms; Poisonous mushrooms. Types of edible mushrooms available in India - *Volvariella volvacea, Pleurotus citrinopileatus*, *Agaricus bisporus*.

Unit II **9 lectures**

Cultivation Technology : Infrastructure: substrates (locally available) Polythene bag, vessels, Inoculation hook, inoculation loop, low cost stove, sieves, culture rack, mushroom unit (Thatched house) water sprayer, tray, small polythene bag. Pure culture: Medium, sterilization, preparations of spawn, multiplication. Mushroom bed preparation - paddy straw, sugarcane trash, maize straw, banana leaves. Factors affecting the mushroom bed preparation- Low cost technology, Composting technology in mushroom production.

Unit III **7 lectures**

Storage and nutrition: Short-term storage (Refrigeration – up to 24 hours) Long term Storage (canning, pickels, papads), drying, storage in salt solutions. Nutrition - Proteins - amino acids, mineral elements nutrition - Carbohydrates, Crude fibre content - Vitamins.

Unit IV **7 lectures**

Food Preparation: Types of foods prepared from mushroom. Research Centres - National level and Regional level. Cost benefit ratio - Marketing in India and abroad, Export Value.

Suggested Readings

1. Marimuthu, T. Krishnamoorthy, A.S. Sivaprakasam, K. and Jayarajan. R (1991) Oyster Mushrooms, Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore.
2. Swaminathan, M. (1990) Food and Nutrition. Bappco, The Bangalore Printing and Publishing Co. Ltd., No. 88, Mysore Road, Bangalore - 560018.
3. Tewari, Pankaj and Kapoor, S.C., (1988). Mushroom cultivation, Mittal Publications, Delhi.
4. Nita Bahl (1984-1988) Hand book of Mushrooms, II Edition, Vol. I & Vol. II.

(The above mentioned courses are indicative. Based on the facilities/expertise available, more similar courses can be introduced. The list of courses offered/recommended by UGC may also be considered/referred to while designing new courses/incorporating revision in the courses. References/Text books may be incorporated as per requirements/necessities of the subject concerned).

Expert Committee Members of Learning Outcomes based Curriculum Framework (LOCF) Chemistry

Prof. Nand Kumar Yadav 'Indu', Vice Chancellor, Central University of Jharkhand, Ratu Lohardaga Road, Brambe, Ranchi, Jharkhand

Prof. Shridhar P. Gejji, Head, CAS Department of Chemistry, University of Pune, Pune

Prof. S. Chandrasekhar, CAS Department of Organic Chemistry, Indian Institute of Science, Bangalore

Prof. K.K. Bhasin, Emeritus Professor, CAS Deptt. of Chemistry, Panjab University, Chandigarh

Co-opted Members:

Professor Debashis Chatterjee, Analytical Section, Department of Chemistry, Kalyani University, Nadia, West Bengal

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Learning Outcomes based Curriculum Framework (LOCF)

B.A./B.Sc. (Hons) Mathematics
&
B.A./B.Sc. with Mathematics as a Subject
2019

ज्ञान-विज्ञान विमुक्तये

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.

DPSingh

New Delhi
30th July, 2019

(Prof. D. P. Singh)
Chairman
University Grants Commission

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Preamble

The LOCF (Learning Outcomes based Curriculum Framework) committee constituted by University Grants Commission (UGC) is pleased to submit its report concerning the syllabi for B.A./B.Sc. (Honours) Mathematics and B.A./B.Sc. with Mathematics as a subject. The committee discussed the framework of syllabi in its meetings and suggests the implementation of these syllabi in the Departments/Schools of Mathematics in Universities/Colleges/Institutes based on following facts:

1. The learning outcomes of each paper are designed so that these may help learners to understand the main objectives of studying the course.

2. This will enable learners to select elective papers depending on the individual inclinations and contemporary requirements.

3. The objectives of LOCF are to mentally prepare the students to learn Mathematics leading to graduate degree with honours in Mathematics or with Mathematics as a subject.

4. These syllabi in Mathematics under CBCS are recommended keeping in view of the wide applications of Mathematics in science, engineering, social science, business and a host of other areas.

5. The study of the syllabi will enable the students to be equipped with the state of the art of the subject and will empower them to get jobs in technological and engineering fields as well as in business, education and healthcare sectors.

6. The LOCF committee in Mathematics has prepared this draft paying suitable attention to objectives and learning outcomes of the papers. These syllabi may be implemented with minor modifications with appropriate justifications keeping in view regional, national and international context and needs.

7. The outcomes of each paper may be modified as per the local requirements.

8. The text books mentioned in references are denotative/demonstrative. The divisions of each paper in units are specified to the context mentioned in courses. These units will help the learners to complete the study of concerned paper in certain periods and prepare them for examinations.

9. The papers are organized considering the credit load in a particular semester. The core papers of general interest are suggested for semesters I to IV. The elective courses and advanced courses are proposed for the B.A./B.Sc. (Hons.) students of semesters V & VI and the elective courses for the students of B.A./B.Sc. semesters V & VI having Mathematics as a subject.

10. The mathematics is a vast subject with immense diversity. Hence it is very difficult for every student to learn each branch of mathematics, even though each paper has its unique importance.

Under these circumstances, LOCF in Mathematics suggests a number of elective papers along with compulsory papers. A student can select elective papers as per her/his needs and interests.

11. The committee expects that the papers may be taught using various Computer Algebra Systems (CAS) softwares such as Mathematica, MATLAB, Maxima and R to strengthen the conceptual understanding and to widen up the horizon of students' self-experience.

12. The committee of the LOCF in Mathematics expects that the concerned departments/colleges/institutes/universities will encourage their faculty members to include necessary topics in addition to courses suggested by LOCF committee. It is hoped that the needs of all round development in the careers of learners/students will be fulfilled by the recommendations of LOCF in Mathematics.

Learning Outcomes-based Curriculum Framework in B.A./B.Sc. (Hons) Mathematics & B.A./B.Sc. with Mathematics as a subject

1. Introduction

One of the significant reforms in the undergraduate education is to introduce the Learning Outcomes-based Curriculum Framework (LOCF) which makes it student-centric, interactive and outcome-oriented with well-defined aims, objectives and goals to achieve. Outcome based learning is the principal end of pedagogical transactions in higher education in today's world in the light of exponential changes brought about in science and technology, especially in mathematics, and the prevalent utilitarian world view of the society. The learning outcomes are attained by students through skills acquired during a programme of study. Programme learning outcomes will include subject-specific skills and generic skills, including transferable global skills and competencies. It would also focus on knowledge and skills that prepare students for further study, employment, and citizenship. They help ensure comparability of learning levels and academic standards across colleges/universities and provide a broad picture of the level of competence of graduates.

The quality education in a subject like mathematics is a very challenging task for Higher Education System in India. UGC has already taken an appropriate measure to define the minimum levels of learning for mathematics courses for undergraduate and post-graduate levels. The quality of higher education in mathematics should be improved in such a manner that young minds are able to compete in this field globally in terms of their knowledge and skills in the globalised era of the date. Also, there is an urgent need of sustained initiatives to be taken by colleges/institutes/universities for outcome-oriented higher education in mathematics so that graduates are enabled to enhance the chances of employability. Presently, the goal of higher education in mathematics may be achieved using the following measures:

i. Curriculum reform based on a learning outcomes-based curriculum framework (LOCF).
ii. Improving learning environment and academic resources.
iii. Elevating the quality of teaching and research.

iv. Involving students in discussions, problem-solving and out of box thinking about various ideas of mathematics and their applicability, which may lead to empowerment and enhancement of the social welfare at large.

v. Encouraging the learners to make use of LOCF to learn mathematics through distance education.

vi. Motivating the learners to understand various concepts of mathematics keeping in view the regional context.

vii. Enabling learners to create research atmosphere in mathematical sciences in their colleges/institutes/universities.

viii. Teach courses of mathematics based on Choice Based Credit System (CBCS).

One of the benchmarks to measure the progress of a country is the advancement of the knowledge of mathematics. Hence, innovative measures should be taken to improve the quality of mathematical knowledge in our society. This is also because mathematics has wide ranging applications in engineering, technology and a host of other areas.

2. Learning Outcomes-based approach to Curriculum Planning

The Bachelor's Degree in B.A./B.Sc. (Hons) Mathematics and B.A./B.Sc. with Mathematics as a subject, is awarded to the students on the basis of knowledge, understanding, skills, attitudes, values and academic achievements sought to be acquired by learners at the end of these programmes. Hence, the learning outcomes of mathematics for these courses are aimed at facilitating the learners to acquire these attributes, keeping in view of their preferences and aspirations for knowledge of mathematics.

The LOCF in mathematics has designed courses in the light of graduate attributes, description of qualifications, courses and programme learning outcomes. The committee has tried to frame the syllabi of mathematics in such a way that it may lead to all round development and delivery of complete curriculum planning. Hence, it provides specific guidelines to the learners to acquire sufficient knowledge during this programme.

The objectives of LOCF (Mathematics) is to prepare the syllabi having standard level of study. It is also aimed at prescribing standard norms for teaching-learning process and examination pattern. Hence, the programme has been chalked out in such manner that there is scope of flexibility and innovation in

i. modifications of prescribed syllabi.
ii. teaching-learning methodology.
iii. assessment technique of students and knowledge levels.
iv. learning outcomes of courses.
v. inclusion of new elective courses subject to availability of experts in colleges/institutes/universities across the country.

2.1. Nature and extent of Bachelor's Degree Programme

Mathematics is the study of quantity, structure, space and change. It has very broad scope in science, engineering and social sciences. The key areas of study in mathematics are:

1. Calculus
2. Algebra
3. Geometry
4. Differential Equations
5. Analysis
6. Mechanics

Degree programs in mathematics cover topics which are already mentioned in details under various headings in Section 6. The depth and breadth of study of individual topics depend on the nature and devotion of learners in specific mathematics programmes.

As a part of effort to enhance employability of mathematics graduates, the courses have been designed to include learning experiences, which offer them opportunities in various sectors of human activities. In this context, the experience of the project work in the areas of applications of mathematics has a key role.

2.2. Aims of Bachelor's degree programme in Mathematics

The overall aims of B.A./B.Sc. (Hons) Mathematics and B.A./B.Sc. with Mathematics as a subject are to

- create deep interest in learning mathematics.
- develop broad and balanced knowledge and understanding of definitions, concepts, principles and theorems.
- familiarize the students with suitable tools of mathematical analysis to handle issues and problems in mathematics and related sciences.
- enhance the ability of learners to apply the knowledge and skills acquired by them during the programme to solve specific theoretical and applied problems in mathematics.
- provide students/learners sufficient knowledge and skills enabling them to undertake further studies in mathematics and its allied areas on multiple disciplines concerned with mathematics.
- encourage the students to develop a range of generic skills helpful in employment, internships and social activities.

2.3. Key outcomes underpinning curriculum planning and development

The LOCF in Mathematics desires to propose the courses of mathematics for B.A./B.Sc. (Hons) Mathematics and B.A./B.Sc. with Mathematics as a subject, based on the expected learning outcomes and academic standards which are necessary for the graduates after completing these programmes. The committee considered and discussed the following factors seriously:

i. Framing of syllabi
ii. Learners attributes
iii. Qualification descriptors
iv. Programme learning outcomes
v. Course learning outcomes
vi. Necessity of having elective courses
vii. Applications of mathematics
viii. Employability in banking, finance and other sectors.

3. Graduate Attributes in Mathematics

The graduate attributes in mathematics are the summation of the expected course learning outcomes mentioned in the beginning of each course. Some of them are stated below.

3.1. Disciplinary knowledge:

Capability of demonstrating comprehensive knowledge of mathematics and understanding of one or more disciplines which form a part of an undergraduate programme of study.

3.2. Communications skills:

i. Ability to communicate various concepts of mathematics effectively using examples and their geometrical visualizations.
ii. Ability to use mathematics as a precise language of communication in other branches of human knowledge.
iii. Ability to communicate long standing unsolved problems in mathematics.
iv. Ability to show the importance of mathematics as precursor to various scientific developments since the beginning of the civilization.
v. Ability to explain the development of mathematics in the civilizational context and its role as queen of all sciences.

3.3. Critical thinking and analytical reasoning:

i. Ability to employ critical thinking in understanding the concepts in every area of mathematics.
ii. Ability to analyze the results and apply them in various problems appearing in different branches of mathematics.

3.4. Problem solving:

i. Capability to solve problems in computer graphics using concepts of linear algebra.
ii. Capability to solve various models such as growth and decay models, radioactive decay model, drug assimilation, LCR circuits and population models using techniques of differential equations.
iii. Ability to solve linear system of equations, linear programming problems and network flow problems.
iv. Ability to provide new solutions using the domain knowledge of mathematics

acquired during this programme.

3.5. Research-related skills:

i. Capability for inquiring about appropriate questions relating to the concepts in various fields of mathematics.
ii. To know about the advances in various branches of mathematics.

3.6. Information/digital literacy:

i. Capability to use appropriate softwares to solve system of equations and differential equations.
ii. Capability to understand and apply the programming concepts of C++ to mathematical investigations and problem solving.

3.7. Self-directed learning:

Ability to work independently and do in-depth study of various notions of mathematics.

3.8. Moral and ethical awareness/reasoning:

Ability to identify unethical behaviour such as fabrication, falsification or misrepresentation of data and adopting objective, unbiased and truthful actions in all aspects.

3.9. Lifelong learning:

Ability to think, acquire knowledge and skills through logical reasoning and to inculcate the habit of self-learning.

4. Qualification descriptors for B.A./B.Sc. (Hons) Mathematics and B.A./B.Sc. with Mathematics as a subject

The qualification descriptor suggests the generic outcomes and attributes to be obtained while obtaining the degree of B.A./B.Sc. (Hons) Mathematics or B.A./B.Sc. with Mathematics as a subject. The qualification descriptors indicate the academic standards on the basis of following factors:

i. Level of knowledge
ii. Understanding
iii. Skills
iv. Competencies and attitudes
v. Values.

These parameters are expected to be attained and demonstrated by the learners after becoming graduates in these programmes. The colleges/institutes/universities should consider the above mentioned parameters at the time of designing, approving, assessing and reviewing academic programmes containing common courses for B.A./B.Sc. (Hons) Mathematics as well as B.A./B.Sc. with Mathematics as a subject. The learning experiences and assessment procedures should be so designed that every graduate with mathematics may achieve the programme learning outcomes with equal opportunity irrespective of the class, gender, community and regions. Each graduate in mathematics should be able to:

i. demonstrate fundamental systematic knowledge of mathematics and its applications in engineering, science, technology and mathematical sciences. It should also enhance the subject specific knowledge and help in creating jobs in various sectors.
ii. demonstrate educational skills in areas of analysis, geometry, algebra, mechanics, differential equations etc.
iii. apply knowledge, understanding and skills to identify the difficult/unsolved problems in mathematics and to collect the required information in possible range of sources and try to analyse and evaluate these problems using appropriate methodologies.
iv. fulfil one's learning requirements in mathematics, drawing from a range of contemporary research works and their applications in diverse areas of mathematical sciences.
v. apply one's disciplinary knowledge and skills in mathematics in newer domains and uncharted areas.
vi. identify challenging problems in mathematics and obtain well-defined solutions.
vii. exhibit subject-specific transferable knowledge in mathematics relevant to job trends and employment opportunities.

5. Programme Learning Outcomes of B.A./B.Sc. (Hons) Mathematics and B.A./B.Sc. with Mathematics as a Subject

1. Bachelor's degree in mathematics is the culmination of in-depth knowledge of algebra, calculus, geometry, differential equations and several other branches of mathematics. This also leads to study of related areas like computer science and statistics. Thus, this programme helps learners in building a solid foundation for higher studies in mathematics.

2. The skills and knowledge gained has intrinsic beauty, which also leads to proficiency in analytical reasoning. This can be utilised in modelling and solving real life problems.

3. Students undergoing this programme learn to logically question assertions, to recognise patterns and to distinguish between essential and irrelevant aspects of problems. They also share ideas and insights while seeking and benefitting from knowledge and insight of others. This helps them to learn behave responsibly in a rapidly changing interdependent society.

4. Students completing this programme will be able to present mathematics clearly and precisely, make vague ideas precise by formulating them in the language of mathematics, describe mathematical ideas from multiple perspectives and explain fundamental concepts of mathematics to non-mathematicians.

5. Completion of this programme will also enable the learners to join teaching profession in primary and secondary schools.

6. This programme will also help students to enhance their employability for government jobs, jobs in banking, insurance and investment sectors, data analyst jobs and jobs in various other public and private enterprises.

6. Structure of B.A./B.Sc. Mathematics

6.1. Course learning outcomes

Course learning outcomes of each course in B.A./B.Sc. (Hons) Mathematics and B.A./B.Sc. with Mathematics as a subject have been enshrined in the beginning of course contents of each course.

B.A./B.Sc. (Hons) Mathematics

CORE COURSES (14)

Programme outcomes	Calculus	Algebra and Geometry	Multivariable Calculus	Ordinary Differential Equations	Real Analysis	Group Theory	Probability and Statistics	Mechanics	Linear Algebra	Partial Differential Equations and Calculus of Variations	Set Theory and Metric Spaces	Advanced Algebra	Complex Analysis	Numerical Analysis
Disciplinary knowledge	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Communication skills	√	√	√	√	√	√	√		√	√	√	√	√	
Critical thinking	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Analytical thinking	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Problem solving	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Research related skills				√						√		√	√	
Information literacy	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Digital literacy			√				√							√
Self-directed learning	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Lifelong learning	√	√	√	√	√		√			√	√	√	√	√
Professional skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Applicational skills	√		√	√			√	√	√	√				√
Experimental learning	√	√	√	√	√		√	√	√	√			√	√
Employability options	√		√				√		√	√				√

DISCIPLINE SPECIFIC ELECTIVE COURSES (Any Four)

Programme	Tensors and Differential Gemetry	Mathematical Logic	Integral Transforms and Fourier Analysis	Linear Programming	Information Theory and Coding	Graph Theory	Special Theory and Relativity	Discrete Mathematics	Wavelets and Applications	Number Theory	Mathematical Finance	C++ Programming for Mathematics	Cryptography	Advanced Mechanics	Dissertation on Any Topic of Mathematics
Disciplinary knowledge	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Communication skills	√	√			√	√		√	√		√	√		√	
Critical thinking	√	√	√	√	√	√		√	√	√	√	√	√	√	√
Analytical thinking	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Problem solving	√	√	√	√	√	√	√	√	√	√	√		√	√	
Research related skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
Information literacy			√	√	√				√			√			
Digital literacy			√	√	√				√			√			
Self-directed learning	√	√	√	√	√	√		√	√	√	√	√		√	√
Lifelong learning	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Professional skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
Applicational skills			√	√	√	√		√	√		√	√	√		
Experimental learning				√	√	√		√	√		√	√	√		
Employability options				√	√			√	√		√	√	√		

B.A./B.Sc. with Mathematics as a Subject

CORE COURSES (4)

Programme outcomes	Calculus	Algebra	Differential Equations	Real Analysis
Disciplinary knowledge	√	√	√	√
Communication skills	√	√	√	√
Critical thinking	√	√	√	√
Analytical thinking	√	√	√	√
Problem solving	√	√	√	√
Research related skills		√	√	√
Information literacy	√	√		√
Digital literacy		√		
Self-directed learning	√	√	√	√
Lifelong learning	√		√	√
Professional skills	√	√	√	√
Applicational skills	√		√	
Experimental learning	√	√	√	
Employability options			√	

DISCIPLINE SPECIFIC ELECTIVE COURSES (Any Two)

Programme outcomes	Mechanics	Probability and Statistics	Numerical Methods	Complex Variables	Linear Algebra	Integral Transforms and Fourier Analysis	Discrete Mathematics	Linear Programming and Game Theory	Tensors and Differential Geometry	Number Theory	Advanced Mechanics	Information Theory and Coding	Special Theory of Relativity	C++ Programming for Mathematics
Disciplinary knowledge	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Communication skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Critical thinking	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Analytical thinking	√		√		√	√		√	√		√	√	√	√
Problem solving	√	√	√		√	√	√	√				√	√	√
Research related skills			√			√						√	√	√
Information literacy		√	√		√	√	√	√		√		√	√	
Digital literacy		√	√		√	√	√	√		√		√	√	√
Self-directed learning	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Lifelong learning	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Professional skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Applicational skills		√	√		√	√	√	√		√		√	√	√
Experimental learning		√	√		√	√	√	√				√	√	
Employability options	√	√	√	√	√	√	√	√	√	√	√	√	√	√

6.1.1. Credit distribution for B.A./B.Sc. (Hons) Mathematics

Sl. No.	Nature of Papers	Total No. of Papers	Credits in Theory+(Tutorial/Practical)	Total Credits
1.	Core Papers	14	06	84
2.	DSE (Discipline Specific Electives) Papers	04	06	24
3.	Generic Electives /Interdisciplinary	04	06	24
4.	Ability Enhancement Papers	02	04	08
5.	Skill Enhancement Papers	02	04	08
Total Papers/Credits		28	--	148

6.1.2. Credit distribution for B.A./B.Sc. with Mathematics as a subject

S. No.	Nature of Papers	Total No. of Papers	Credits in Theory + Tutorial	Total Credits
1.	Core Papers	04	06	24
2.	DSE (Discipline Specific Elective) Papers	02	06	12
3.	Skill Enhancement Papers	02	04	08
Total Papers/Credits		06		44

6.2. Contents for each course

6.2.1. Contents of courses for B.A./B.Sc. (Hons) Mathematics

Semesters	Core Courses	DSE Courses
I	**Paper-101:** Calculus **Paper-102:** Algebra and Geometry	
II	**Paper-201:** Multivariable Calculus **Paper-202:** Ordinary Differential Equations	
III	**Paper-301:** Real Analysis **Paper-302:** Group Theory **Paper-303:** Probability and	

	Statistics	
IV	**Paper-401:**Mechanics **Paper-402:** Linear Algebra **Paper-403:** Partial Differential Equations and Calculus of Variations	
V	**Paper-501:** Set Theory and Metric Spaces **Paper-502:** Advanced Algebra	**(Any Two)** **Paper-503 & 504 (i)-(vii)** **Paper-(i):** Tensors and Differential Geometry **Paper-(ii):** Mathematical Logic **Paper-(iii):** Integral Transforms and Fourier Analysis **Paper-(iv):** Linear Programming **Paper-(v):** Information Theory and Coding **Paper-(vi):** Graph Theory **Paper-(vii):** Special Theory and Relativity
VI	**Paper-601:** Complex Analysis **Paper-602:** Numerical Analysis	**(Any Two)** **Paper-603 &604 (i)-(viii)** **Paper-(i):** Discrete Mathematics **Paper-(ii):** Wavelets and Applications **Paper-(iii):** Number Theory **Paper-(iv):** Mathematical Finance **Paper-(v):** C++Programming for Mathematics **Paper-(vi):** Cryptography **Paper-(vii):** Advanced Mechanics **Paper-(viii):** Dissertation on Any Topic of Mathematics

Semester-I

Paper-101: Calculus

Course Learning Outcomes: This course will enable the students to:

i) Assimilate the notions of limit of a sequence and convergence of a series of real numbers.
ii) Calculate the limit and examine the continuity of a function at a point.
iii) Understand the consequences of various mean value theorems for differentiable functions.
iv) Sketch curves in Cartesian and polar coordinate systems.
v) Apply derivative tests in optimization problems appearing in social sciences, physical sciences, life sciences and a host of other disciplines.

Unit-I: Sequences and Integration

Real numbers, Sequences of real numbers, Convergence of sequences and series, Bounded and monotonic sequences; Definite integral as a limit of sum, Integration of irrational algebraic functions and transcendental functions, Reduction formulae, Definite integrals.

Unit-II: Limit and Continuity

ε-δ definition of limit of a real valued function, Limit at infinity and infinite limits; Continuity of a real valued function, Properties of continuous functions, Intermediate value theorem, Geometrical interpretation of continuity, Types of discontinuity; Uniform continuity.

Unit-III: Differentiability

Differentiability of a real valued function, Geometrical interpretation of differentiability, Relation between differentiability and continuity, Differentiability and monotonicity, Chain rule of differentiation; Darboux's theorem, Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem, Geometrical interpretation of mean value theorems; Successive differentiation, Leibnitz's theorem.

Unit-IV: Expansions of Functions

Maclaurin's and Taylor's theorems for expansion of a function in an infinite series, Taylor's theorem in finite form with Lagrange, Cauchy and Roche–Schlomilch forms of remainder; Maxima and minima.

Unit-V: Curvature, Asymptotes and Curve Tracing

Curvature; Asymptotes of general algebraic curves, Parallel asymptotes, Asymptotes parallel to axes; Symmetry, Concavity and convexity, Points of inflection, Tangents at origin, Multiple points, Position and nature of double points; Tracing of Cartesian, polar and parametric curves.

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Paper-102: Algebra and Geometry

Course Learning Outcomes: This course will enable the students to:

i) Understand the importance of roots of real and complex polynomials and learn various methods of obtaining roots.
ii) Familiarize with relations, equivalence relations and partitions.
iii) Employ De Moivre's theorem in a number of applications to solve numerical problems.
iv) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix, using rank.
v) Find eigenvalues and corresponding eigenvectors for a square matrix.
vi) Explain the properties of three dimensional shapes.

Unit-I: Theory of Equations and Complex Numbers

Elementary theorems on the roots of an equations including Cardan's method, The remainder and factor theorems, Synthetic division, Factored form of a polynomial, The Fundamental theorem of algebra, Relations between the roots and the coefficients of polynomial equations, Imaginary roots, Integral and rational roots; Polar representation of complex numbers, The n^{th} roots of unity, De Moivre's theorem for integer and rational indices and its applications.

Unit-II: Relations and Basic Number Theory

Relations, Equivalence relations, Equivalence classes; Functions, Composition of functions, Inverse of a function; Finite, countable and uncountable sets; The division algorithm, Divisibility and the Euclidean algorithm, The fundamental theorem of arithmetic, Modular arithmetic and basic properties of congruences; Principles of mathematical induction and well ordering.

Unit-III: Row Echelon Form of Matrices and Applications

Systems of linear equations, Row reduction and echelon forms, Linear independence, The rank of a matrix and applications; Introduction to linear transformations, The matrix of a linear transformation, Matrix operations, Determinants, The inverse of a matrix, Characterizations of invertible matrices; Applications to Computer Graphics; Eigenvalues and eigenvectors, The characteristic equation and the Cayley–Hamilton theorem.

Unit-IV: Planes, Straight Lines and Spheres

Planes: Distance of a point from a plane, Angle between two planes, pair of planes, Bisectors of angles between two planes; Straight lines: Equations of straight lines, Distance of a point from a straight line, Distance between two straight lines, Distance between a straight line and a plane; Spheres: Different forms, Intersection of two spheres, Orthogonal intersection, Tangents and normal, Radical plane, Radical line, Coaxial system of spheres, Pole, Polar and Conjugacy.

Unit-V: Locus, Surfaces, Curves and Conicoids

Space curves, Algebraic curves, Ruled surfaces, Some standard surfaces, Classification of quadric surfaces, Cone, Cylinder, Central conicoids, Tangent plane, Normal, Polar planes, and Polar lines.

References:

1. Titu Andreescu, & Dorin Andrica (2014). *Complex Numbers from A to...Z*. (2nd edition). Birkhäuser.
2. Robert J. T. Bell (1994). *An Elementary Treatise on Coordinate Geometry of Three Dimensions*. Macmillan India Ltd.
3. D. Chatterjee (2009). *Analytical Geometry: Two and Three Dimensions*. Narosa Publishing House.
4. Leonard Eugene Dickson (2009). *First Course in the Theory of Equations*. The Project Gutenberg EBook (http://www.gutenberg.org/ebooks/29785)
5. Edgar G. Goodaire & Michael M. Parmenter (2015). *Discrete Mathematics with Graph Theory* (3rd edition). Pearson Education Pvt. Ltd. India.
6. Bernard Kolman & David R. Hill (2003). *Introductory Linear Algebra with Applications* (7th edition). Pearson Education Pvt. Ltd. India.
7. David C. Lay, Steven R. Lay & Judi J. McDonald (2016). *Linear Algebra and its Applications* (5th edition). Pearson Education Pvt. Ltd. India.

Semester-II

Paper-201: Multivariable Calculus

Course Learning Outcomes: This course will enable the students to:

i) Learn conceptual variations while advancing from one variable to several variables in calculus.

ii) Apply multivariable calculus in optimization problems.

iii) Inter-relationship amongst the line integral, double and triple integral formulations.

iv) Applications of multivariable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

v) Realize importance of Green, Gauss and Stokes' theorems in other branches of mathematics.

Unit-I: Partial Differentiation

Functions of several variables, Level curves and surfaces, Limits and continuity, Partial differentiation, Tangent planes, Chain rule, Directional derivatives, The gradient, Maximal and normal properties of the gradient, Tangent planes and normal lines.

Unit-II: Differentiation

Higher order partial derivatives, Total differential and differentiability, Jacobians, Change of variables, Euler's theorem for homogeneous functions, Taylor's theorem for functions of two variables and more variables, Envelopes and evolutes.

Unit-III: Extrema of Functions and Vector Field

Extrema of functions of two and more variables, Method of Lagrange multipliers, Constrained optimization problems, Definition of vector field, Divergence, curl, gradient and vector identities.

Unit-IV: Double and Triple Integrals

Double integration over rectangular and nonrectangular regions, Double integrals in polar co-ordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals, Triple integration in cylindrical and spherical coordinates, Change of variables in double and triple integrals, Dirichlet integral.

Unit-V: Green's, Stokes' and Gauss Divergence Theorem

Line integrals, Applications of line integrals**:** Mass and Work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral, Surface integrals, Stokes' theorem, The Gauss divergence theorem.

References:

1. Jerrold Marsden, Anthony J. Tromba & Alan Weinstein (2009). *Basic Multivariable Calculus*, Springer India Pvt. Limited.
2. James Stewart (2012). *Multivariable Calculus* (7th edition). Brooks/Cole. Cengage.
3. Monty J. Strauss, Gerald L. Bradley & Karl J. Smith (2011). *Calculus* (3rd edition). Pearson Education. Dorling Kindersley (India) Pvt. Ltd.
4. George B. Thomas Jr., Joel Hass, Christopher Heil & Maurice D. Weir (2018). *Thomas*' *Calculus* (14th edition). Pearson Education.

Paper-202: Ordinary Differential Equations

Course Learning Outcomes: The course will enable the students to:

i) Understand the genesis of ordinary differential equations.

ii) Learn various techniques of getting exact solutions of solvable first order differential equations and linear differential equations of higher order.

iii) Know Picard's method of obtaining successive approximations of solutions of first order differential equations, passing through a given point in the plane and Power series method for higher order linear equations, especially in cases when there is no method available to solve such equations.

iv) Grasp the concept of a general solution of a linear differential equation of an arbitrary order and also learn a few methods to obtain the general solution of such equations.

v) Formulate mathematical models in the form of ordinary differential equations to suggest possible solutions of the day to day problems arising in physical, chemical and biological disciplines.

Unit-I: First Order Differential Equations

Basic concepts and genesis of ordinary differential equations, Order and degree of a differential equation, Differential equations of first order and first degree, Equations in which variables are separable, Homogeneous equations, Linear differential equations and equations reducible to linear form, Exact differential equations, Integrating factor, First order higher degree equations solvable for x, y and p. Clairaut's form and singular solutions. Picard's method of successive approximations and the statement of Picard's theorem for the existence and uniqueness of the solutions of the first order differential equations.

Unit-II: Second Order Linear Differential Equations

Statement of existence and uniqueness theorem for linear differential equations, General theory of linear differential equations of second order with variable coefficients, Solutions of homogeneous linear ordinary differential equations of second order with constant coefficients, Transformations of the equation by changing the dependent/independent variable, Method of variation of parameters and method of undetermined coefficients, Reduction of order, Coupled linear differential equations with constant coefficients.

Unit-III: Higher Order Linear Differential Equations

Principle of superposition for a homogeneous linear differential equation, Linearly dependent and linearly independent solutions on an interval, Wronskian and its properties, Concept of a general solution of a linear differential equation, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler-Cauchy equation, Method of variation of parameters and method of undetermined coefficients, Inverse operator method.

Unit-IV: Series Solutions of Differential Equations

Power series method, Legendre's equation, Legendre polynomials, Rodrigue’s formula, Orthogonality of Legendre polynomials, Frobenius method, Bessel's equation, Bessel functions and their properties, Recurrence relations.

Unit-V: Applications

Orthogonal trajectories, Acceleration-velocity model, Minimum velocity of escape from Earth’s gravitational field, Growth and decay models, Malthusian and logistic population models, Radioactive decay, Drug assimilation into the blood of a single cold pill; Free and forced mechanical oscillations of a spring suspended vertically carrying a mass at its lowest tip, Phenomena of resonance, LCR circuits, Lotka–Volterra population model.

References:

1. Belinda Barnes & Glenn Robert Fulford (2015). *Mathematical Modelling with Case Studies*: *A Differential Equation Approach Using* Maple *and* MATLAB (2nd edition). Chapman & Hall/CRC Press, Taylor & Francis.
2. H. I. Freedman (1980). *Deterministic Mathematical Models in Population Ecology*. Marcel Dekker Inc.
3. Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10th edition). Wiley.
4. Daniel A. Murray (2003). *Introductory Course in Differential Equations*, Orient.
5. B. Rai, D. P. Choudhury & H. I. Freedman (2013). *A Course in Ordinary Differential Equations* (2nd edition). Narosa.
6. Shepley L. Ross (2007). *Differential Equations* (3rd edition), Wiley India.
7. George F. Simmons (2017). *Differential Equations with Applications and Historical Notes* (3rd edition). CRC Press. Taylor & Francis.

Semester-III

Paper-301: Real Analysis

Course Learning Outcomes: This course will enable the students to:

i) Understand many properties of the real line $\mathbb{R}$ and learn to define sequence in terms of functions from $\mathbb{R}$ to a subset of $\mathbb{R}$.

ii) Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.

iii) Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.

iv) Learn some of the properties of Riemann integrable functions, and the applications of the fundamental theorems of integration.

Unit-I: Real Number System

Algebraic and order properties of $\mathbb{R}$, Absolute value of a real number; Bounded above and bounded below sets, Supremum and infimum of a nonempty subset of $\mathbb{R}$,The completeness property of $\mathbb{R}$, Archimedean property, Density of rational numbers in $\mathbb{R}$, Definition and types of intervals, Nested intervals property; Neighborhood of a point in $\mathbb{R}$, Open, closed and perfect sets in $\mathbb{R}$, Connected subsets of $\mathbb{R}$, Cantor set and Cantor function.

Unit-II: Sequences of Real Numbers

Convergent sequence, Limit of a sequence, Bounded sequence, Limit theorems, Monotone sequences, Monotone convergence theorem, Subsequences, Bolzano−Weierstrass theorem for sequences, Limit superior and limit inferior of a sequence of real numbers, Cauchy sequence, Cauchy's convergence criterion.

Unit-III: Infinite Series

Convergence and divergence of infinite series of positive real numbers, Necessary condition for convergence, Cauchy criterion for convergence; Tests for convergence of positive term series**;** Basic comparison test, Limit comparison test, D'Alembert's ratio test, Cauchy's n^{th} root test, Integral test; Alternating series, Leibniz test, Absolute and conditional convergence, Rearrangement of series and Riemann's theorem.

Unit-IV: Riemann Integration

Riemann integral, Integrability of continuous and monotonic functions, Fundamental theorem of integral calculus, First mean value theorem, Bonnet and Weierstrass forms of second mean value theorems.

Unit-V: Uniform convergence and Improper integral:

Pointwise and uniform convergence of sequence and series of functions, Weierstrass's M-test, Dirichlet test and Abel's test for uniform convergence, Uniform convergence and continuity, Uniform convergence and differentiability, Improper integrals, Dirichlet test and Abel's test for improper integrals.

References:

1. Robert G. Bartle & Donald R. Sherbert (2015). *Introduction to Real Analysis* (4th edition).Wiley India.
2. Gerald G. Bilodeau, Paul R. Thie & G. E. Keough (2015). *An Introduction to Analysis* (2nd edition), Jones and Bartlett India Pvt. Ltd.
3. K. A. Ross (2013). *Elementary Analysis*: *The Theory of Calculus* (2nd edition). Springer.

Paper-302: Group Theory

Course Learning Outcomes: The course will enable the students to:

i) Recognize the mathematical objects called groups.
ii) Link the fundamental concepts of groups and symmetries of geometrical objects.
iii) Explain the significance of the notions of cosets, normal subgroups, and factor groups.
iv) Analyze consequences of Lagrange's theorem.
v) Learn about structure preserving maps between groups and their consequences.

Unit-I: Groups and its Elementary Properties

Symmetries of a square, Definition and examples of groups including dihedral, permutation and quaternion groups, Elementary properties of groups.

Unit-II: Subgroups and Cyclic Groups

Subgroups and examples of subgroups, Cyclic groups, Properties of cyclic groups, Lagrange's theorem, Euler phi function, Euler's theorem, Fermat's little theorem.

Unit-III: Normal Subgroups

Properties of cosets, Normal subgroups, Simple groups, Factor groups, Cauchy's theorem for finite abelian groups; Centralizer, Normalizer, Center of a group, Product of two subgroups; Classification of subgroups of cyclic groups.

Unit-IV: Permutation Groups

Cycle notation for permutations, Properties of permutations, Even and odd permutations, alternating groups, Cayley's theorem and its applications.

Unit-V: Group Homomorphisms, Rings and Fields

Group homomorphisms, Properties of homomorphisms, Group isomorphisms, Properties of isomorphisms; First, second and third isomorphism theorems for groups; Definitions and elementary properties of rings and fields.

References:

1. Michael Artin (2014). *Algebra* (2nd edition). Pearson.
2. John B. Fraleigh (2007). *A First Course in Abstract Algebra* (7th edition). Pearson.
3. Joseph A. Gallian (2017). *Contemporary Abstract Algebra* (9th edition). Cengage.
4. I. N. Herstein (2006). *Topics in Algebra* (2nd edition). Wiley India.
5. Nathan Jacobson (2009). *Basic Algebra* I (2nd edition). Dover Publications.

6. Ramji Lal (2017). *Algebra 1: Groups, Rings, Fields and Arithmetic*. Springer.
7. I.S. Luthar & I.B.S. Passi (2013). *Algebra: Volume 1: Groups*. Narosa.

Paper-303: Probability and Statistics

Course Learning Outcomes: This course will enable the students to:

i) Understand distributions in the study of the joint behaviour of two random variables.

ii) Establish a formulation helping to predict one variable in terms of the other that is, correlation and linear regression.

iii) Understand central limit theorem, which establish the remarkable fact that the empirical frequencies of so many natural populations, exhibit a bell shaped curve.

Unit-I: Probability Functions and Moment Generating Function

Basic notions of probability, Conditional probability and independence, Baye's theorem; Random variables - Discrete and continuous, Cumulative distribution function, Probability mass/density functions; Transformations, Mathematical expectation, Moments, Moment generating function, Characteristic function.

Unit-II: Univariate Discrete and Continuous Distributions

Discrete distributions**:** Uniform, Bernoulli, Binomial, Negative binomial, Geometric and Poisson; Continuous distributions**:** Uniform, Gamma, Exponential, Chi-square, Beta and normal; Normal approximation to the binomial distribution.

Unit-III: Bivariate Distribution

Joint cumulative distribution function and its properties, Joint probability density function, Marginal distributions, Expectation of function of two random variables, Joint moment generating function, Conditional distributions and expectations.

Unit-IV: Correlation, Regression and Central Limit Theorem

The Correlation coefficient, Covariance, Calculation of covariance from joint moment generating function, Independent random variables, Linear regression for two variables, The method of least squares, Bivariate normal distribution, Chebyshev's theorem, Strong law of large numbers, Central limit theorem and weak law of large numbers.

Unit-V: Modeling Uncertainty

Uncertainty, Information and entropy, Uniform Priors, Polya's urn model and random graphs.

References:

1. Robert V. Hogg, Joseph W. McKean & Allen T. Craig (2013). *Introduction to Mathematical Statistics* (7th edition), Pearson Education.

2. Irwin Miller &Marylees Miller (2014). *John E. Freund's Mathematical Statistics with Applications* (8th edition). Pearson. Dorling Kindersley Pvt. Ltd. India.
3. Jim Pitman (1993). *Probability*, Springer-Verlag.
4. Sheldon M. Ross (2014). *Introduction to Probability Models* (11th edition). Elsevier.
5. A. M. Yaglom and I. M. Yaglom (1983). *Probability and Information*. D. Reidel Publishing Company. Distributed by Hindustan Publishing Corporation (India) Delhi.

Semester-IV

Paper-401: Mechanics

Course Learning Outcomes: This course will enable the students to:

i) Familiarize with subject matter, which has been the single centre, to which were drawn mathematicians, physicists, astronomers, and engineers together.

ii) Understand necessary conditions for the equilibrium of particles acted upon by various forces and learn the principle of virtual work for a system of coplanar forces acting on a rigid body.

iii) Determine the centre of gravity of some materialistic systems and discuss the equilibrium of a uniform cable hanging freely under its own weight.

iv) Deal with the kinematics and kinetics of the rectilinear and planar motions of a particle including the constrained oscillatory motions of particles.

v) Learn that a particle moving under a central force describes a plane curve and know the Kepler's laws of the planetary motions, which were deduced by him long before the mathematical theory given by Newton.

Unit-I: Statics

Equilibrium of a particle, Equilibrium of a system of particles, Necessary conditions of equilibrium, Moment of a force about a point, Moment of a force about a line, Couples, Moment of a couple, Equipollent system of forces, Work and potential energy, Principle of virtual work for a system of coplanar forces acting on a particle or at different points of a rigid body, Forces which can be omitted in forming the equations of virtual work.

Unit-II: Centres of Gravity and Common Catenary

Centres of gravity of plane area including a uniform thin straight rod, triangle, circular arc, semicircular area and quadrant of a circle, Centre of gravity of a plane area bounded by a curve, Centre of gravity of a volume of revolution; Flexible strings, Common catenary, Intrinsic and Cartesian equations of the common catenary, Approximations of the catenary.

Unit-III: Rectilinear Motion

Simple harmonic motion (SHM) and its geometrical representation, SHM under elastic forces, Motion under inverse square law, Motion in resisting media, Concept of terminal velocity, Motion of varying mass.

Unit-IV: Motion in a Plane

Kinematics and kinetics of the motion, Expressions for velocity and acceleration in Cartesian, polar and intrinsic coordinates; Motion in a vertical circle, projectiles in a vertical plane and cycloidal motion.

Unit-V: Central Orbits

Equation of motion under a central force, Differential equation of the orbit, (p, r) equation of the orbit, Apses and apsidal distances, Areal velocity, Characteristics of central orbits, Kepler's laws of planetary motion

References:

1. S. L. Loney (2006). *An Elementary Treatise on the Dynamics of a Particle and of Rigid Bodies*. Read Books.
2. P. L. Srivatava (1964). *Elementary Dynamics*. Ram Narin Lal, Beni Prasad Publishers Allahabad.
3. J. L. Synge & B. A. Griffith (1949). *Principles of Mechanics*. McGraw-Hill.
4. A. S. Ramsey (2009). *Statics*. Cambridge University Press.
5. A. S. Ramsey (2009). *Dynamics*. Cambridge University Press.
6. R. S. Varma (1962). *A Text Book of Statics*. Pothishala Pvt. Ltd.

Paper-402: Linear Algebra

Course Learning Outcomes: This course will enable the students to:

i) Understand the concepts of vector spaces, subspaces, bases, dimension and their properties.
ii) Relate matrices and linear transformations, compute eigen values and eigen vectors of linear transformations.
iii) Learn properties of inner product spaces and determine orthogonality in inner product spaces.
iv) Realise importance of adjoint of a linear transformation and its canonical form.

Unit-I: Vector Spaces

Definition and examples, Subspace, Linear span, Quotient space and direct sum of subspaces, Linearly independent and dependent sets, Bases and dimension.

Unit-II: Linear Transformations

Definition and examples, Algebra of linear transformations, Matrix of a linear transformation, Change of coordinates, Rank and nullity of a linear transformation and rank-nullity theorem.

Unit-III: Further Properties of Linear Transformations

Isomorphism of vector spaces, Isomorphism theorems, Dual and second dual of a vector space, Transpose of a linear transformation, Eigen vectors and eigen values of a linear transformation, Characteristic polynomial and Cayley–Hamilton theorem, Minimal polynomial.

Unit-IV: Inner Product Spaces

Inner product spaces and orthogonality, Cauchy–Schwarz inequality, Gram–Schmidt orthogonalisation, Diagonalisation of symmetric matrices.

Unit-V: Adjoint of a Linear Transformation and Canonical Forms

Adjoint of a linear operator; Hermitian, unitary and normal linear transformations; Jordan canonical form, Triangular form, Trace and transpose, Invariant subspaces.

References:

1. Stephen H. Friedberg, Arnold J. Insel & Lawrence E. Spence (2003). *Linear Algebra* (4th edition). Prentice-Hall of India Pvt. Ltd.
2. Kenneth Hoffman & Ray Kunze (2015). *Linear Algebra* (2nd edition). Prentice-Hall.
3. I. M. Gel'fand (1989). *Lectures on Linear Algebra.* Dover Publications.

4. Nathan Jacobson (2009). *Basic Algebra* I & II (2nd edition). Dover Publications.
5. Serge Lang (2005). *Introduction to Linear Algebra* (2nd edition). Springer India.
6. Vivek Sahai & Vikas Bist (2013). *Linear Algebra* (2nd Edition). Narosa Publishing House.
7. Gilbert Strang (2014). *Linear Algebra and its Applications* (2nd edition). Elsevier.

Paper-403: Partial Differential Equations and Calculus of Variations

Course Learning Outcomes: This course will enable the students to:

i) Apply a range of techniques to solve first & second order partial differential equations.

ii) Model physical phenomena using partial differential equations such as the heat and wave equations.

iii) Understand problems, methods and techniques of calculus of variations.

Unit-I: First Order Partial Differential Equations

Order and degree of Partial differential equations (PDE), Concept of linear and non-linear partial differential equations, Partial differential equations of the first order, Lagrange's method, Some special type of equation which can be solved easily by methods other than the general method, Charpit's general method.

Unit-II: Second Order Partial Differential Equations with Constant Coefficients

Classification of linear partial differential equations of second order, Homogeneous and non-homogeneous equations with constant coefficients.

Unit-III: Second Order Partial Differential Equations with Variable Coefficients

Partial differential equations reducible to equations with constant coefficient, Second order PDE with variable coefficients, Classification of second order PDE, Reduction to canonical or normal form; Monge's method; Solution of heat and wave equations in one and two dimensions by method of separation of variables.

Unit-IV: Calculus of Variations-Variational Problems with Fixed Boundaries

Euler's equation for functional containing first order and higher order total derivatives, Functionals containing first order partial derivatives, Variational problems in parametric form, Invariance of Euler's equation under coordinates transformation.

Unit-V: Calculus of Variations-Variational Problems with Moving Boundaries

Variational problems with moving boundaries, Functionals dependent on one and two variables, One sided variations. Sufficient conditions for an extremum-Jacobi and Legendre conditions, Second variation.

References:

1. A. S. Gupta (2004). *Calculus of Variations with Applications*. PHI Learning.

2. Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10^{th} edition). Wiley.
3. TynMyint-U & Lokenath Debnath (2013). *Linear Partial Differential Equation for Scientists and Engineers* (4^{th} edition). Springer India.
4. H. T. H. Piaggio (2004). An Elementary Treatise on *Differential Equations and Their Applications.* CBS Publishers.
5. S. B. Rao & H. R. Anuradha (1996). *Differential Equations with Applications*. University Press.
6. Ian N. Sneddon (2006). *Elements of Partial Differential Equations*. Dover Publications.

Semester-V

Paper-501: Set Theory and Metric Spaces

Course Learning Outcomes: This course will enable the students to:

i) Learn basic facts about the cardinality of a set.

ii) Understand several standard concepts of metric spaces and their properties like openness, closedness, completeness, Bolzano−Weierstrass property, compactness, and connectedness.

iii) Identify the continuity of a function defined on metric spaces and homeomorphisms.

Unit-I: Theory of Sets

Finite and infinite sets, Countable and uncountable sets, Cardinality of sets, Schröder−Bernstein theorem, Cantor's theorem, Order relation in cardinal numbers, Arithmetic of cardinal numbers, Partially ordered set, Zorn's lemma and Axiom of choice, Various set theoretic paradoxes.

Unit-II: Concepts in Metric Spaces

Definition and examples of metric spaces, Open spheres and closed spheres, Neighbourhoods, Open sets, Interior, exterior and boundary points, Closed sets, Limit points and isolated points, Interior and closure of a set, Boundary of a set, Bounded sets, Distance between two sets, Diameter of a set, Subspace of a metric space.

Unit-III: Complete Metric Spaces and Continuous Functions

Cauchy and Convergent sequences, Completeness of metric spaces, Cantor's intersection theorem, Dense sets and separable spaces, Nowhere dense sets and Baire's category theorem, Continuous and uniformly continuous functions, Homeomorphism, Banach contraction principle.

Unit-IV: Compactness

Compact spaces, Sequential compactness, Bolzano−Weierstrass property, Compactness and finite intersection property, Heine−Borel theorem, Totally bounded sets, Equivalence of compactness and sequential compactness, Continuous functions on compact spaces.

Unit-V: Connectedness

Separated sets, Disconnected and connected sets, Components, Connected subsets of $\mathbb{R}$, Continuous functions on connected sets.

References:

1. E. T. Copson (1988). *Metric Spaces*. Cambridge University Press.
2. P. R. Halmos (1974). *Naive Set Theory*. Springer.
3. P. K. Jain & Khalil Ahmad (2019). *Metric Spaces*. Narosa.
4. S. Kumaresan (2011). *Topology of Metric Spaces* (2nd edition). Narosa.
5. Satish Shirali & Harikishan L. Vasudeva (2006). *Metric Spaces*. Springer-Verlag.
6. Micheál O'Searcoid (2009). *Metric Spaces*. Springer-Verlag.
7. G. F. Simmons (2004). *Introduction to Topology and Modern Analysis*. McGraw-Hill.

Paper-502: Advanced Algebra

Course Learning Outcomes: This course will enable the students to:

i) Understand the basic concepts of group actions and their applications.
ii) Recognize and use the Sylow theorems to characterize certain finite groups.
iii) Know the fundamental concepts in ring theory such as the concepts of ideals, quotient rings, integral domains, and fields.
iv) Learn in detail about polynomial rings, fundamental properties of finite field extensions, and classification of finite fields.

Unit-I: Group Actions

Group actions, Orbits and stabilizers, Conjugacy classes, Orbit-stabilizer theorem, Normalizer of an element of a group, Center of a group, Class equation of a group, Inner and outer automorphisms of a group.

Unit-II: Sylow Theorems

Cauchy's theorem for finite abelian groups, Finite simple groups, Sylow theorems and applications including nonsimplicity tests.

Unit-III: Rings and Fields

Definition, examples and elementary properties of rings, Commutative rings, Integral domain, Division rings and fields, Characteristic of a ring, Ring homomorphisms and isomorphisms, Ideals and quotient rings. Prime, principal and maximal ideals, Relation between integral domain and field, Euclidean rings and their properties, Wilson and Fermat's theorems.

Unit-IV: Polynomial Rings

Polynomial rings over commutative ring and their basic properties, The division algorithm; Polynomial rings over rational field, Gauss lemma and Eisenstein's criterion, Euclidean domain, principal ideal domain, and unique factorization domain.

Unit-V: Field Extensions and Finite Fields

Extension of a field, Algebraic element of a field, Algebraic and transcendental numbers, Perfect field, Classification of finite fields.

References:

1. Michael Artin (2014). *Algebra* (2nd edition). Pearson.

2. P. B. Bhattacharya, S. K. Jain & S. R. Nagpaul (2003). *Basic Abstract Algebra* (2nd edition). Cambridge University Press.
3. David S. Dummit & Richard M. Foote (2008). *Abstract Algebra* (2nd edition). Wiley.
4. John B. Fraleigh (2007). *A First Course in Abstract Algebra* (7th edition). Pearson.
5. Joseph A. Gallian (2017). *Contemporary Abstract Algebra* (9th edition). Cengage.
6. N. S. Gopalakrishnan (1986). *University Algebra*, New Age International Publishers.
7. I. N. Herstein (2006). *Topics in Algebra* (2nd edition). Wiley India.
8. Thomas W. Hungerford (2004). *Algebra* (8th edition). Springer.
9. Nathan Jacobson (2009). *Basic Algebra I & II* (2nd edition). Dover Publications.
10. Serge Lang (2002). *Algebra* (3rd edition). Springer-Verlag.
11. I. S. Luthar & I. B. S. Passi (2013). *Algebra: Volume 1: Groups*. Narosa.
12. I. S. Luthar & I. B. S. Passi (2012). *Algebra: Volume 2: Rings*. Narosa.

Elective Courses (Any Two)
(Paper-503 & 504 (i)-(vii))
Paper-(i):Tensors and Differential Geometry

Course Learning Outcomes: This course will enable the students to:

i) Explain the basic concepts of tensors.
ii) Understand role of tensors in differential geometry.
iii) Learn various properties of curves including Frenet–Serret formulae and their applications.
iv) Know the Interpretation of the curvature tensor, Geodesic curvature, Gauss and Weingarten formulae.
v) Understand the role of Gauss's Theorema Egregium and its consequences.
vi) Apply problem-solving with differential geometry to diverse situations in physics, engineering and in other mathematical contexts.

Unit-I: Tensors

Contravariant and covariant vectors, Transformation formulae, Tensor product of two vector spaces, Tensor of type (r, s), Symmetric and skew-symmetric properties, Contraction of tensors, Quotient law, Inner product of vectors.

Unit-II: Further Properties of Tensors

Fundamental tensors, Associated covariant and contravariant vectors, Inclination of two vectors and orthogonal vectors, Christoffel symbols, Law of transformation of Christoffel symbols, Covariant derivatives of covariant and contravariant vectors, Covariant differentiation of tensors, Curvature tensor, Ricci tensor, Curvature tensor identities.

Unit-III: Curves in $\mathbb{R}^2$ and $\mathbb{R}^3$

Basic definitions and examples, Arc length, Curvature and the Frenet–Serret formulae, Fundamental existence and uniqueness theorem for curves, Non-unit speed curves.

Unit-IV: Surfaces in $\mathbb{R}^3$

Basic definitions and examples, The first fundamental form, Arc length of curves on surfaces, Normal curvature, Geodesic curvature, Gauss and Weingarten formulae, Geodesics, Parallel vector fields along a curve and parallelism.

Unit-V: Geometry of Surfaces

The second fundamental form and the Weingarten map; Principal, Gauss and mean curvatures; Isometries of surfaces, Gauss's Theorema Egregium, The fundamental theorem of surfaces, Surfaces of constant Gauss curvature, Exponential map, Gauss lemma, Geodesic coordinates, The Gauss–Bonnet formula and theorem.

References:

1. Christian Bär (2010). *Elementary Differential Geometry*. Cambridge University Press.
2. Manfredo P. do Carmo (2016). *Differential Geometry of Curves & Surfaces* (Revised and updated 2nd edition). Dover Publications.
3. Alferd Gray (2018). *Modern Differential Geometry of Curves and Surfaces with Mathematica* (4th edition). Chapman & Hall/CRC Press, Taylor & Francis.
4. Richard S. Millman & George D. Parkar (1977). *Elements of Differential Geometry*. Prentice-Hall.
5. R. S. Mishra (1965). *A Course in Tensors with Applications to Riemannian Geometry*. Pothishala Pvt. Ltd.
6. Sebastián Montiel & Antonio Ross (2009). *Curves and Surfaces*. American Mathematical Society.

Paper-(ii): Mathematical Logic

Course Learning Outcomes: This course will enable the students to:

i) Learn the syntax of first-order logic and semantics of first-order languages.

ii) Understand the propositional logic and basic theorems like compactness theorem, meta theorem and post-tautology theorem.

iii) Assimilate the concept of completeness interpretations and their applications with special emphasis on applications in algebra.

Unit-I: Syntax of First-order Logic

First-order languages, Terms of language, Formulas of language, First order theory.

Unit-II: Semantics of First-order Languages

Structures of first order languages, Truth in a structure, Model of a theory, Embeddings and isomorphism.

Unit-III: Propositional Logics

Syntax of propositional logic, Semantics of propositional logic, Compactness theorem for propositional logic, Proof in propositional logic, Meta theorem in propositional logic, Post tautology theorem.

Unit-IV: Proof and Meta Theorems in First-order Logic

Proof in first-order logic, Meta theorems in first-order logic, Some meta theorem in arithmetic, Consistency and completeness.

Unit-V: Completeness Theorem and Model Theory

Completeness theorem, Interpretation in a theory, Extension by definitions, Compactness theorem and applications, Complete theories, Applications in algebra.

References:

1. Richard E. Hodel (2013). *An Introduction to Mathematical Logic.* Dover Publications.
2. Yu I. Manin (2010). *A Course in Mathematical Logic for Mathematicians* (2nd edition). Springer.
3. Elliott Mendelson (2015). *Introduction to Mathematical Logic* (6th edition). Chapman & Hall/CRC.
4. Shashi Mohan Srivastava (2013). *A Course on Mathematical Logic* (2nd edition). Springer.

Paper-(iii): Integral Transforms and Fourier Analysis

Course Learning Outcomes: This course will enable the students to:

i) Know about piecewise continuous functions, Dirac delta function, Laplace transforms and its properties.

ii) Solve ordinary differential equations using Laplace transforms.

iii) Familiarise with Fourier transforms of functions belonging to $L^1(\mathbb{R})$ class, relation between Laplace and Fourier transforms.

iv) Explain Parseval's identity, Plancherel's theorem and applications of Fourier transforms to boundary value problems.

v) Learn Fourier series, Bessel's inequality, term by term differentiation and integration of Fourier series.

vi) Apply the concepts of the course in real life problems.

Unit-I: Laplace Transforms

Laplace transform, Linearity, Existence theorem, Laplace transforms of derivatives and integrals, Shifting theorems, Change of scale property, Laplace transforms of periodic functions, Dirac's delta function.

Unit-II: Further Properties of Laplace Transforms and Applications

Differentiation and integration of transforms, Convolution theorem, Integral equations, Inverse Laplace transform, Lerch's theorem, Linearity property of inverse Laplace transform, Translations theorems of inverse Laplace transform, Inverse transform of derivatives, Applications of Laplace transform in obtaining solutions of ordinary differential equations and integral equations.

Unit-III: Fourier Transforms

Fourier and inverse Fourier transforms, Fourier sine and cosine transforms, Inverse Fourier sine and cosine transforms, Linearity property, Change of scale property, Shifting property, Modulation theorem, Relation between Fourier and Laplace transforms.

Unit-IV: Solution of Equations by Fourier Transforms

Solution of integral equation by Fourier sine and cosine transforms, Convolution theorem for Fourier transform, Parseval's identity for Fourier transform, Plancherel's theorem, Fourier transform of derivatives, Applications of infinite Fourier transforms to boundary value problems, Finite Fourier transform, Inversion formula for finite Fourier transforms.

Unit-V: Fourier Series

Fourier cosine and sine series, Fourier series, Differentiation and integration of Fourier series, Absolute and uniform convergence of Fourier series, Bessel's inequality, The complex form of Fourier series.

References:

1. James Ward Brown & Ruel V. Churchill (2011). F*ourier Series and Boundary Value Problems*. McGraw-Hill Education.
2. Charles K. Chui (1992). *An Introduction to Wavelets*. Academic Press.
3. Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10th edition). Wiley.
4. Walter Rudin (2017). *Fourier Analysis on Groups*. Dover Publications.
5. A. Zygmund (2002).*Trigonometric Series* (3rd edition). Cambridge University Press.

Paper-(iv): Linear Programming

Course Learning Outcomes: This course will enable the students to:

i) Analyze and solve linear programming models of real life situations.

ii) Provide graphical solutions of linear programming problems with two variables, and illustrate the concept of convex set and extreme points.

iii) Understand the theory of the simplex method.

iv) Know about the relationships between the primal and dual problems, and to understand sensitivity analysis.

v) Learn about the applications to transportation, assignment and two-person zero-sum game problems.

Unit-I: Linear Programming Problem, **Convexity and Basic Feasible Solutions**

Formulation**,** Canonical and standard forms, Graphical method; Convex and polyhedral sets, Hyperplanes, Extreme points; Basic solutions, Basic Feasible Solutions, Reduction of feasible solution to basic feasible solution, Correspondence between basic feasible solutions and extreme points.

Unit-II: Simplex Method

Optimality criterion, Improving a basic feasible solution, Unboundedness, Unique and alternate optimal solutions; Simplex algorithm and its tableau format; Artificial variables, Two-phase method, Big-M method.

Unit-III: Duality

Formulation of the dual problem, Duality theorems, Complimentary slackness theorem, Economic interpretation of the dual, Dual-simplex method.

Unit-IV: Sensitivity Analysis

Changes in the cost vector, right-hand side vector and the constraint matrix of the linear programming problem.

Unit-V: Applications

*Transportation Problem***:** Definition and formulation, Methods of finding initial basic feasible solutions: Northwest-corner rule, Least- cost method, Vogel approximation method; Algorithm for obtaining optimal solution.

*Assignment Problem***:** Mathematical formulation and Hungarian method.

*Game Theory***:** Formulation and solution of two-person zero-sum games, Games with mixed strategies, Linear programming method for solving a game.

References:

1. Mokhtar S. Bazaraa, John J. Jarvis & Hanif D. Sherali (2010). *Linear Programming and Network Flows* (4th edition). John Wiley & Sons.
2. G. Hadley (2002). *Linear Programming*. Narosa Publishing House.
3. Frederick S. Hillier & Gerald J. Lieberman (2015). *Introduction to Operations Research* (10th edition). McGraw-Hill Education.
4. Hamdy A. Taha (2017). *Operations Research*: *An Introduction* (10th edition). Pearson.
5. Paul R. Thie & Gerard E. Keough (2014). *An Introduction to Linear Programming and Game Theory* (3rd edition). Wiley India Pvt. Ltd.

Paper-(v): Information Theory and Coding

Course Learning Outcomes: This course will enable the students to:

i) Study simple ideal statistical communication models.

ii) Understand the development of codes for transmission and detection of information.

iii) Learn about the input and output of a signal via transmission channel.

iv) Study detection and correction of errors during transmission.

v) Represent a linear code by matrices - encoding and decoding.

Unit-I: Concepts of Information Theory

Communication processes, A model of communication system, A quantitative measure of information, Binary unit of information, A measure of uncertainty, H function as a measure of uncertainty, Sources and binary sources, Measure of information for two-dimensional discrete finite probability schemes.

Unit-II: Entropy Function

A sketch of communication network, Entropy, Basic relationship among different entropies, A measure of mutual information, Interpretation of Shannon's fundamental inequalities; Redundancy, efficiency, and channel capacity; Binary symmetric channel, Binary erasure channel, Uniqueness of the entropy function, Joint entropy and conditional entropy, Relative entropy and mutual information, Chain rules for entropy, Conditional relative entropy and conditional mutual information, Jensen's inequality and its characterizations, The log sum inequality and its applications.

Unit-III: Concepts of Coding

Block codes, Hamming distance, Maximum likelihood decoding, Levels of error handling, Error correction, Error detection, Erasure correction, Construction of finite fields, Linear codes, Matrix representation of linear codes, Hamming codes.

Unit-IV: Bounds of Codes

Orthogonality relation, Encoding and decoding of linear codes, The singleton bound and maximum distance separable codes, The sphere-packing bound and perfect codes, The Gilbert–Varshamov bound, MacWilliams' identities.

Unit-V: Cyclic Codes

Definition and examples of cyclic codes, Generator polynomial and check polynomial, Generator matrix and check matrix, Bose–Chaudhuri–Hocquenghem (BCH) code as a cyclic code.

References:

1. Robert B. Ash, (2014). *Information Theory*. Dover Publications.
2. Thomas M. Cover & Joy A. Thomas (2013). *Elements of Information Theory* (2nd edition). Wiley India Pvt. Ltd.
3. Joseph A. Gallian (2017). *Contemporary Abstract Algebra* (9th edition), Cengage.
4. Fazlollah M. Reza, (2003). *An Introduction to Information Theory*. Dover Publications.
5. Ron M. Roth (2007). *Introduction to Coding Theory*. Cambridge University Press.
6. Claude E. Shannon & Warren Weaver (1969). *The Mathematical Theory of Communication*. The University of Illinios Press.

Paper-(vi): Graph Theory

Course Learning Outcomes: This course will enable the students to:

i) Appreciate the definition and basics of graphs along with types and their examples.
ii) Understand the definition of a tree and learn its applications to fundamental circuits.
iii) Know the applications of graph theory to network flows.
iv) Understand the notion of planarity and coloring of a graph.
v) Relate the graph theory to the real-world problems.

Unit-I: Paths, Circuits and Graph Isomorphisms

Definition and examples of a graph, Subgraph, Walks, Paths and circuits; Connected graphs, disconnected graphs and components of a graph; Euler and Hamiltonian graphs, Graph isomorphisms, Adjacency matrix and incidence matrix of a graph, Directed graphs and their elementary properties.

Unit-II: Trees and Fundamental Circuits

Definition and properties of trees, Rooted and binary trees, Cayley's theorem on a counting tree, Spanning tree, Fundamental circuits, Minimal spanning trees in a connected graph.

Unit-III: Cut-Sets and Cut-Vertices

Cut-set of a graph and its properties, Fundamental circuits and cut-sets, Cut-vertices, Connectivity and separability, Network flows, 1- isomorphism and 2- isomorphism.

Unit-IV: Planar Graphs

Planar graph, Euler theorem for a planar graph, Various representations of a planar graph, Dual of a planar graph, Detection of planarity, Kuratowski's theorem.

Unit-V: Graph Coloring

Chromatic number of a graph, Chromatic partition, Chromatic polynomial, Matching and coverings, Four color problem.

References:

1. R. Balakrishnan & K. Ranganathan (2012). *A Textbook of Graph Theory*. Springer.
2. Narsingh Deo (2016). *Graph Theory with Applications to Engineering and Computer Science*. Dover Publications.
3. Reinhard Diestel (2017). *Graph Theory* (5^{th} edition). Springer.
4. Edgar G. Goodaire & Michael M. Parmenter (2018). *Discrete Mathematics with Graph Theory* (3^{rd} edition). Pearson.
5. Douglas West (2017). *Introduction to Graph Theory* (2^{nd} edition). Pearson.

Paper-(vii): Special Theory of Relativity

Course Learning Outcomes: This course will enable the students to:

i) Understand the basic elements of Newtonian mechanics including Michelson–Morley experiment and geometrical interpretations of Lorentz transformation equations.
ii) Learn about length contraction, time dilation and Lorentz contraction factor.
iii) Study 4-dimensional Minkowskian space-time and its consequences.
iv) Understand equations of motion as a part of relativistic mechanics.
v) Imbibe connections between relativistic mechanics and electromagnetism.

Unit-I: Newtonian Mechanics

Inertial frames, Speed of light and Gallilean relativity, Michelson–Morley experiment, Lorentz–Fitzgerold contraction hypothesis, Relative character of space and time, Postulates of special theory of relativity, Lorentz transformation equations and its geometrical interpretation, Group properties of Lorentz transformations.

Unit-II: Relativistic Kinematics

Composition of parallel velocities, Length contraction, Time dilation, Transformation equations for components of velocity and acceleration of a particle and Lorentz contraction factor.

Unit-III: Geometrical representation of space-time

Four dimensional Minkowskian space-time of special relativity, Time-like, light-like and space-like intervals, Null cone, Proper time, World line of a particle, Four vectors and tensors in Minkowiskian space-time.

Unit-IV: Relativistic Mechanics

Variation of mass with velocity. Equivalence of mass and energy. Transformation equations for mass momentum and energy. Energy-momentum four vector. Relativistic force and Transformation equations for its components. Relativistic equations of motion of a particle.

Unit-V: Electromagnetism

Transformation equations for the densities of electric charge and current. Transformation equations for electric and magnetic field strengths. The Field of a Uniformly Moving Point charge. Forces and fields near a current carrying wire. Forces between moving charges. The invariance of Maxwell`s equations.

References:

1. James L. Anderson (1973). *Principles of Relativity Physics*. Academic Press.
2. Peter Gabriel Bergmann (1976). *Introduction to the Theory of Relativity*. Dover Publications.
3. C. Moller (1972). *The Theory of Relativity* (2nd edition). Oxford University Press.
4. Robert Resnick (2007). *Introduction to Special Relativity*. Wiley.
5. Wolfgang Rindler (1977). *Essential Relativity: Special, General, and Cosmological*. Springer-Verlag.
6. V. A. Ugarov (1979). *Special Theory of Relativity*. Mir Publishers, Moscow.

Semester-VI

Paper-601: Complex Analysis

Course Learning Outcomes: This course will enable the students to:

i) Visualize complex numbers as points of $\mathbb{R}^2$ and stereographic projection of complex plane on the Riemann sphere.

ii) Understand the significance of differentiability and analyticity of complex functions leading to the Cauchy–Riemann equations.

iii) Learn the role of Cauchy–Goursat theorem and Cauchy integral formula in evaluation of contour integrals.

iv) Apply Liouville's theorem in fundamental theorem of algebra.

v) Understand the convergence, term by term integration and differentiation of a power series.

vi) Learn Taylor and Laurent series expansions of analytic functions, classify the nature of singularity, poles and residues and application of Cauchy Residue theorem.

Unit-I: Complex Plane and functions.

Complex numbers and their representation, algebra of complex numbers; Complex plane, Open set, Domain and region in complex plane; Stereographic projection and Riemann sphere; Complex functions and their limits including limit at infinity; Continuity, Linear fractional transformations and their geometrical properties.

Unit-II: Analytic Functions and Cauchy–Riemann Equations

Differentiability of a complex valued function, Cauchy–Riemann equations, Harmonic functions, necessary and sufficient conditions for differentiability, Analytic functions; Analyticity and zeros of exponential, trigonometric and logarithmic functions; Branch cut and branch of multi-valued functions.

Unit-III: Cauchy's Theorems and Fundamental Theorem of Algebra

Line integral, Path independence, Complex integration, Green's theorem, Anti-derivative theorem, Cauchy–Goursat theorem, Cauchy integral formula, Cauchy's inequality, Derivative of analytic function, Liouville's theorem, Fundamental theorem of algebra, Maximum modulus theorem and its consequences.

Unit-IV: Power Series

Sequences, series and their convergence, Taylor series and Laurent series of analytic functions, Power series, Radius of convergence, Integration and differentiation of power series, Absolute and uniform convergence of power series.

Unit-V: Singularities and Contour Integration

Meromorphic functions, Zeros and poles of meromorphic functions, Nature of singularities, Picard's theorem, Residues, Cauchy's residue theorem, Argument principle, Rouche's theorem, Jordan's lemma, Evaluation of proper and improper integrals.

References:

1. Lars V. Ahlfors (2017). *Complex Analysis* (3rd edition). McGraw-Hill Education.
2. Joseph Bak & Donald J. Newman (2010). *Complex Analysis* (3rd edition). Springer.
3. James Ward Brown & Ruel V. Churchill (2009). *Complex Variables and Applications* (9th edition). McGraw-Hill Education.
4. John B. Conway (1973). *Functions of One Complex Variable*. Springer-Verlag.
5. E.T. Copson (1970). *Introduction to Theory of Functions of Complex Variable*. Oxford University Press.
6. Theodore W. Gamelin (2001). *Complex Analysis*. Springer-Verlag.
7. George Polya & Gordon Latta (1974). *Complex Variables*. Wiley.
8. H. A. Priestley (2003). *Introduction to Complex Analysis*. Oxford University Press.
9. E. C. Titchmarsh (1976). *Theory of Functions* (2nd edition). Oxford University Press.

Paper-602: Numerical Analysis

Course Learning Outcomes: This course will enable the students to:

i) Obtain numerical solutions of algebraic and transcendental equations.

ii) Find numerical solutions of system of linear equations and check the accuracy of the solutions.

iii) Learn about various interpolating and extrapolating methods.

iv) Solve initial and boundary value problems in differential equations using numerical methods.

v) Apply various numerical methods in real life problems.

Unit-I: Numerical Methods for Solving Algebraic and Transcendental Equations

Round-off error and computer arithmetic, Local and global truncation errors, Algorithms and convergence; Bisection method, False position method, Fixed point iteration method, Newton's method and secant method for solving equations.

Unit-II: Numerical Methods for Solving Linear Systems

Partial and scaled partial pivoting, Lower and upper triangular (LU) decomposition of a matrix and its applications, Thomas method for tridiagonal systems; Gauss–Jacobi, Gauss–Seidel and successive over-relaxation (SOR) methods.

Unit-III: Interpolation

Lagrange and Newton interpolations, Piecewise linear interpolation, Cubic spline interpolation, Finite difference operators, Gregory–Newton forward and backward difference interpolations.

Unit-IV: Numerical Differentiation and Integration

First order and higher order approximation for first derivative, Approximation for second derivative; Numerical integration: Trapezoidal rule, Simpson's rules and error analysis, Bulirsch–Stoer extrapolation methods, Richardson extrapolation.

Unit-V: Initial and Boundary Value Problems of Differential Equations

Euler's method, Runge–Kutta methods, Higher order one step method, Multi-step methods; Finite difference method, Shooting method, Real life examples: Google search engine, 1D and 2D simulations, Weather forecasting.

References:

1. Brian Bradie (2006), *A Friendly Introduction to Numerical Analysis.* Pearson.
2. C. F. Gerald & P. O. Wheatley (2008). *Applied Numerical Analysis* (7th edition), Pearson Education, India.
3. F. B. Hildebrand (2013). *Introduction to Numerical Analysis*: (2nd edition). Dover Publications.
4. M. K. Jain, S. R. K. Iyengar & R. K. Jain (2012). *Numerical Methods for Scientific and Engineering Computation* (6th edition). New Age International Publishers.
5. Robert J. Schilling & Sandra L. Harris (1999). *Applied Numerical Methods for Engineers Using* MATLAB *and C*. Thomson-Brooks/Cole.

Elective Courses (Any two)

(Paper-603 &604 (i)-(vii)

Paper-(i): Discrete Mathematics

Course Learning Outcomes: This course will enable the students to:

i) Learn about partially ordered sets, lattices and their types.

ii) Understand Boolean algebra and Boolean functions, logic gates,switching circuitsand their applications.

iii) Solve real-life problems using finite-state and Turing machines.

iv) Assimilate various graph theoretic concepts and familiarize with their applications.

Unit-I: Partially Ordered Sets

Definitions, examples and basic properties of partially ordered sets (poset), Order isomorphism, Hasse diagrams, Dual of a poset, Duality principle, Maximal and minimal elements, Least upper bound and greatest upper bound, Building new poset, Maps between posets.

Unit-II: Lattices

Lattices as posets, Lattices as algebraic structures, Sublattices, Products and homomorphisms; Definitions, examples and properties of modular and distributive lattices; Complemented, relatively complemented and sectionally complemented lattices.

Unit-III:Boolean Algebras and Switching Circuits

Boolean algebras, De Morgan’s laws, Boolean homomorphism, Representation theorem; Boolean polynomials, Boolean polynomial functions, Disjunctive and conjunctive normal forms, Minimal forms of Boolean polynomials, Quine–McCluskey method, Karnaugh diagrams, Switching circuits and applications.

Unit-IV: Finite-State and Turing Machines

Finite-state machines with outputs, and with no output; Deterministic and nodeterministic finite-state automaton; Turing machines: Definition, examples, and computations.

Unit-V: Graphs

Definition, examples and basic properties of graphs, Königsberg bridge problem; Subgraphs, Pseudographs, Complete graphs, Bipartite graphs, Isomorphism of graphs, Paths and circuits, Eulerian circuits, Hamiltonian cycles, Adjacency matrix, Weighted graph, Travelling-salesman problem, Shortest path and Dijkstra’s algorithm.

References:

1. B. A. Davey & H. A. Priestley (2002). *Introduction to Lattices and Order* (2nd edition). Cambridge University Press.
2. Edgar G. Goodaire & Michael M. Parmenter (2018). *Discrete Mathematics with Graph Theory* (3rd edition). Pearson Education.
3. Rudolf Lidl & Günter Pilz (1998). *Applied Abstract Algebra* (2nd edition). Springer.
4. Kenneth H. Rosen (2012). *Discrete Mathematics and its Applications*: *With Combinatorics and Graph Theory* (7th edition). McGraw-Hill.
5. C. L. Liu (1985). *Elements of Discrete Mathematics* (2nd edition). McGraw-Hill.

Paper-(ii): Wavelets and Applications

Course Learning Outcomes: This course will enable the students to:

i) Know basic concepts of signals and systems.

ii) Understand the concept of Haar spaces.

iii) Learn Fourier transform and wavelet transform of digital signals.

iv) Learn applications of wavelets to the real-world problems.

v) Apply wavelets in signal processing and image processing.

Unit-I: Signals and Systems

Basic concepts of signals and systems, Frequency spectrum of signals; Classification of signals: Discrete time signals and continuous time signals, periodic and non-periodic signals; Classification of systems: Linear, nonlinear, time-variant, time-invariant, stable and unstable systems.

Unit-II: Haar Scaling Function and Wavelet, Time-Frequency Analysis

Orthogonal functions, Orthonormal functions, Function spaces, Orthogonal basis functions, Haar scaling function, Haar spaces: Haar space V_0, general Haar space V_j; Haar wavelet, Haar wavelet spaces: Haar wavelet space W_0, general Haar wavelet space W_j; Decomposition and reconstruction, Time-frequency analysis, Orthogonal and orthonormal bases.

Unit–III: Fourier Transforms and Wavelets

Discrete Fourier transform of a digital signal, Complex form of a Fourier series, Inverse discrete Fourier transform, Window Fourier transform, Short time Fourier transform, Admissibility condition for a wavelet, Classes of wavelets: Haar, Morlet, Maxican hat, Meyer and Daubechies wavelets; Wavelets with compact support.

Unit–IV: Discrete Wavelet Transforms

Stationary and non-stationary signals, Haar transform, 1-level Haar transform, Multi-level Haar transform, Conservation and compaction of energy, Multiresolution analysis, Decomposition and reconstruction of signals using discrete wavelet transform (DWT).

Unit–V: Applications

Wavelet series expansion using Haar and other wavelets, Applications in signal compression, Analysis and classification of audio signals using DWT, Signal de-noising: Image and ECG signals.

References:

1. Charles K. Chui (1992). *An Introduction to Wavelets*. Academic Press.
2. Ingrid Daubechies (1999). *Ten Lectures on Wavelets*. SIAM
3. Michael W. Frazier (1999). *An Introduction to Wavelets Through Linear Algebra*. Springer-Verlag.
4. Stéphane Mallat (2008). *A Wavelet Tour of Signal Processing* (3rd edition). Academic Press.
5. M.J. Roberts (2004). *Signals and Systems: Analysis Using Transform Methods and* MATLAB. McGraw-Hill Education.
6. David K. Ruch & Patrick J. Van Fleet (2009), *Wavelet Theory*: *An Elementary Approach with Applications*. John Wiley & Sons.
7. James S. Walker (2008). *A Primer on Wavelets and Their Scientific Applications* (2nd edition). Chapman & Hall/CRC, Taylor & Francis.

Paper-(iii): Number Theory

Course Learning Outcomes: This course will enable the students to:

i) Learn about some important results in the theory of numbers including the prime number theorem, Chinese remainder theorem, Wilson's theorem and their consequences.
ii) Learn about number theoretic functions, modular arithmetic and their applications.
iii) Familiarise with modular arithmetic and find primitive roots of prime and composite numbers.
iv) Know about open problems in number theory, namely, the Goldbach conjecture and twin-prime conjecture.
v) Apply public crypto systems, in particular, RSA.

Unit-I: Distribution of Primes and Theory of Congruencies

Linear Diophantine equation, Prime counting function, Prime number theorem, Goldbach conjecture, Twin-prime conjecture, Odd perfect numbers conjecture, Fermat and Mersenne primes, Congruence relation and its properties, Linear congruence and Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.

Unit-II: Number Theoretic Functions

Number theoretic functions for sum and number of divisors, Multiplicative function, The Möbius inversion formula, Greatest integer function, Euler’s phi-function and properties, Euler’s theorem.

Unit-III: Primitive Roots

Order of an integer modulo *n*, Primitive roots for primes, Composite numbers having primitive roots; Definition of quadratic residue of an odd prime, Euler’s criterion.

Unit-IV: Quadratic Reciprocity Law

The Legendre symbol and its properties, Quadratic reciprocity, Quadratic congruencies with composite moduli.

Unit-V: Applications

Public key encryption, RSA encryption and decryption with applications in security systems.

References:

1. David M. Burton (2007). *Elementary Number Theory* (7^{th} edition). McGraw-Hill.

2. Gareth A. Jones & J. Mary Jones (2005). *Elementary Number Theo*ry. Springer.
3. Neville Robbins (2007). *Beginning Number Theory* (2nd edition). Narosa.
4. I.Niven (2012). *An Introduction to the Theory of Numbers* (5th edition). John Wiley & Sons.
5. Neal Koblitz (1994). *A Course in Number Theory and Cryptography* (2nd edition). Springer-Verlag.

Paper-(iv): Mathematical Finance

Course Learning Outcomes: This course will enable the students to:

i) Understand financial markets and derivatives including options and futures.

ii) Appreciate pricing and hedging of options, interest rate swaps and no-arbitrage pricing concepts.

iii) Learn stochastic analysis, Ito's formula, Ito integral and the Black−Scholes model.

iv) Study and use Hedging parameters, trading strategies and currency swaps.

Unit-I: Basic Theory of Interest and Fixed-Income Securities

Principal and interest: simple, compound and continuous; Present and future value of cash flow streams; Net present value, Internal rates of return and their comparison; Inflation, Annuities; Bonds, Bond prices and yields, Macaulay duration and modified duration.

Unit-II: Term Structure of Interest Rates, Bonds and Derivatives

Spot rates, forward rates and explanations of term structure; Running present value, Floating-rate bonds, Immunization, Convexity; Putable and callable bonds; Exchange-traded markets and over-the-counter markets; Derivatives: Forward contracts, Future contracts, Options, Types of traders, Hedging, Speculation, Arbitrage.

Unit-III: Mechanics of Options Markets

No-arbitrage principle, Short selling, Forward price for an investment asset; Types of options: Call and put options, Option positions, Underlying assets, Factors affecting option prices, Upper and lower bounds for option prices, Put-call parity, Effect of dividends.

Unit-IV: Stochastic Analysis of Stock Prices and Black–Scholes Model

Binomial option pricing model, Risk neutral valuation: European and American options on assets following binomial tree model; Lognormal property of stock prices, Distribution of rate of return, Expected return, Volatility, Estimating volatility from historical data, Extension of risk-neutral valuation to assets following geometric Brownian motion, Black−Scholes formula for European options.

Unit-V: Hedging Parameters, Trading Strategies and Swaps

Hedging parameters: Delta, gamma, theta, rho and vega; Trading strategies involving options, Swaps, Mechanics of interest rate swaps, Comparative advantage argument, Valuation of interest rate swaps, Currency swaps, Valuation of currency swaps.

References:

1. John C. Hull & Sankarshan Basu (2018). *Options, Futures and Other Derivatives* (10th edition). Pearson Education.
2. David G. Luenberger (2013). *Investment Science* (2nd edition). Oxford University Press.
3. Sheldon M. Ross (2011). *An Elementary Introduction to Mathematical Finance* (3rd edition). Cambridge University Press.

Paper-(v): C++Programming for Mathematics

Course Learning Outcomes: This course will enable the students to:

i) Understand and apply the programming concepts of C++ which is important for mathematical investigation and problem solving.
ii) Use mathematical libraries for computational objectives.
iii) Represent the outputs of programs visually in terms of well formatted text and plots.

Unit-I: C++ Essentials

Fundamentals of programming, Organization of logic flow in stored program model of computation, C++ as a general purpose programming language, Structure of a C++ program, Common compilers and IDE's, Basic data-types, Variables and literals in C++, Operators, Expressions, Evaluation precedence and type compatibility; Outline of program development in C++, Debugging and testing; Applications**:** Greatest common divisor and random number generation.

Unit-II: Structured Data

Structured data-types in C++, Arrays and manipulating data in arrays; Objects and classes**:** Information hiding, modularity, constructors and destructors, methods and polymorphism; Applications**:** Factorization of an integer, Euler's totient, Images in Cartesian geometry using points in two & three dimensions, Pythagorean triples.

Unit-III: Containers and Templates

Containers and Template Libraries**:** Sets, iterators, multisets, vectors, maps, lists, stacks and queues; Applications**:** Basic set algebra, modulo arithmetic and congruences, projective plane, permutations, monotone sequences and polynomials.

Unit-IV: Libraries and Packages

Libraries and Packages for arbitrary precision arithmetic and linear algebra**;** Features of C++ for input/output and visualization**:** Strings, streams, formatting methods, processing files in a batch, command-line arguments, visualization packages and their uses; Applications**:** Arbitrary precision arithmetic using GMP, BOOST; Finding nullity, rank, eigen values, eigen vectors, linear transformations, systems of linear equations; Plots.

Unit-V: Odds and Ends

Runtime errors and graceful degradation, Robustness in a program; Exception handling: Try-catch and throw; Defining and deploying suitable exception handlers in programs; Compiler options; Conditional compilation; Understanding and defining suitable pragmas; Applications**:** Identification and description of install parameters of mathematical libraries, debugging installation, working with multiple libraries simultaneously and maintaining correctness and consistency of data.

References:

1. Nell Dale & Chip Weems (2013).*Programming and Problem Solving with C++* (6th edition). Jones & Bartlett Learning.
2. Peter Gottschling (2016). *Discovering Modern C++***:** *An Intensive Course for Scientists, Engineers, and Programmers*. Pearson.
3. Nicolai M. Josuttis (2012). *The C++ Standard Library*: *A Tutorial and Reference* (2nd edition). Addison-Wesley, Pearson.
4. Donald E. Knuth (1968). *The Art of Computer Programming.* Addison-Wesley.
5. Edward Scheinerman (2006). *C++ for Mathematicians*: *An Introduction for Students and Professionals*. Chapman & Hall/CRC. Taylor & Francis.
6. B. Stroustrup (2013). *The C++ Programming Language* (4th edition). Addison-Wesley.

Paper-(vi): Cryptography

Course Learning Outcomes: This course will enable the students to:

i) Understand the difference between classical and modern cryptography.
ii) Learn the fundamentals of cryptography, including Data and Advanced Encryption Standards (DES & AES) and RSA.
iii) Encrypt and decrypt messages using block ciphers, sign and verify messages using well-known signature generation and verification algorithms.
iv) Know about the aspects of number theory which are relevant to cryptography.

Unit I: Introduction to Cryptography and Classical Cryptography

Cryptosystems and basic cryptographic tools: Secret-key cryptosystems, Public-key cryptosystems, Block and stream ciphers, Hybrid cryptography, Message integrity: Message authentication codes, Signature schemes, Nonrepudiation, Certificates, Hash functions, Cryptographic protocols, Security; Hybrid cryptography: Message integrity, Cryptographic protocols, Security, Some simple cryptosystems, Shift cipher, Substitution cipher, Affine cipher, Vigenère cipher, Hill cipher, Permutation cipher, Stream ciphers, Cryptanalysis of affine, substitution, Vigenère, Hill and LFSR stream ciphers.

Unit-II: Cryptographic Security, Pseudo Randomness and Symmetric Key Ciphers

Shannon's theory, Perfect secrecy, Entropy, Spurious keys and unicity distance; Bit generators, Security of pseudorandom bit generators. Substitution-permutation networks, Data encryption standard (DES), Description and analysis of DES; Advanced encryption standard (AES), Description and analysis of AES; Stream ciphers, Trivium.

Unit-III: Basics of Number Theory and Public-Key Cryptography

Basics of number theory; Introduction to public-key cryptography, RSA cryptosystem, Implementing RSA; Primality testing, Legendre and Jacobi symbols, Solovay–Strassen algorithm, Miller–Rabin algorithm; Square roots modulo n, Factoring algorithms, Pollard $p-1$ algorithm, Pollard rho algorithm, Dixon's random squares algorithm, Factoring algorithms in practice; Rabin cryptosystem and its security.

Unit-IV: More on Public-Key Cryptography

Basics of finite fields; ElGamal cryptosystem, Algorithms for the discrete logarithm problem, Shanks' algorithm, Pollard rho discrete logarithm algorithm, Pohlig–Hellman algorithm; Discrete logarithm algorithms in practice, Security of ElGamal systems, Bit security of discrete logarithms.

Unit-V: Hash Functions and Signature Schemes

Hash functions and data integrity, SHA-3; RSA signature scheme, Security requirements for signature schemes, Signatures and Hash functions, ElGamal signature scheme, Security of ElGamal signature scheme, Certificates.

References:

1. Jeffrey Hoffstein, Jill Pipher & Joseph H. Silverman (2014). *An Introduction to Mathematical Cryptography* (2^{nd} edition). Springer.
2. Neal Koblitz (1994). *A Course in Number Theory and Cryptography* (2^{nd} edition). Springer-Verlag.
3. Christof Paar & Jan Pelzl (2014). *Understanding Cryptography*. Springer.
4. Simon Rubinstein-Salzedo (2018). C*ryptography*. Springer.
5. Douglas R. Stinson & Maura B. Paterson (2019). *Cryptography Theory and Practice* (4th edition). Chapman & Hall/CRC Press, Taylor & Francis.

Paper-(vii): Advanced Mechanics

Course Learning Outcomes: This course will enable the students to:

i) Understand the reduction of force system in three dimensions to a resultant force acting at a base point and a resultant couple, which is independent of the choice of base of reduction.
ii) Learn about a nul point, a nul line, and a nul plane with respect to a system of forces acting on a rigid body together with the idea of central axis.
iii) Know the inertia constants for a rigid body and the equation of momental ellipsoid together with the idea of principal axes and principal moments of inertia and to derive Euler's equations of motion of a rigid body, moving about a point which is kept fixed.
iv) Study the kinematics and kinetics of fluid motions to understand the equation of continuity in Cartesian, cylindrical polar and spherical polar coordinates which are used to derive Euler's equations and Bernoulli's equation.
v) Deal with two-dimensional fluid motion using the complex potential and also to understand the concepts of sources, sinks, doublets and the image systems of these with regard to a line and a circle.

Unit-I: Statics in Space

Forces in three dimensions, Reduction to a force and a couple, Equilibrium of a system of particles, Central axis and Wrench, Equation of the central axis, Resultant wrench of two wrenches; Nul points, lines and planes with respect to a system of forces, Conjugate forces and conjugate lines.

Unit-II: Motion of a Rigid Body

Moments and products of inertia of some standard bodies, Momental ellipsoid, Principal axes and moments of inertia; Motion of a rigid body with a fixed point, Kinetic energy of a rigid body with a fixed point and angular momentum of a rigid body, Euler's equations of motion for a rigid body with a fixed point, Velocity and acceleration of a moving particle in cylindrical and spherical polar coordinates, Motion about a fixed axis, Compound pendulum.

Unit-III: Kinematics of Fluid Motion

Lagrangian and Eulerian approaches, Material and convective derivatives, Velocity of a fluid at a point, Equation of continuity in Cartesian, cylindrical polar and spherical polar coordinates, Cylindrical and spherical symmetry, Boundary surface, Streamlines and pathlines, Steady and unsteady flows, Velocity potential, Rotational and irrotational motion, Vorticity vector and vortex lines.

Unit-IV: Kinetics of Fluid Motion

Euler's equations of motion in Cartesian, cylindrical polar and spherical polar coordinates; Bernoulli's equation, Impulsive motion.

Unit-V: Motion in Two-Dimensions

Stream function, Complex potential, Basic singularities: Sources, sinks, doublets, complex potential due to these basic singularities; Image system of a simple source and a simple doublet with regard to a line and a circle, Milne−Thomson circle theorem.

References:

1. A. S. Ramsay (1960). *A Treatise on Hydromechanics, Part-II Hydrodynamics.* G. Bell & Sons.
2. F. Chorlton (1967). *A Textbook of Fluid Dynamics*. CBS Publishers.
3. Michel Rieutord (2015). *Fluid Dynamics An Introduction.* Springer.
4. E. A. Milne (1965). *Vectorial Mechanics*, Methuen & Co.Limited. London.

Paper-(viii): Dissertation on Any Topic of Mathematics

In this course, students are encouraged to choose the topic of their interest and do an in-depth study of the same and with some illuminating real time applications under supervision of a faculty member.

6.2.2. Contents of courses for B.A./B.Sc. with Mathematics as a subject

Semesters	Core Courses	DSE Courses
I	**Paper-M101:** Calculus	
II	**Paper-M201:** Algebra	
III	**Paper-M301:** Differential Equations	
IV	**Paper- M401:**Real Analysis	
V		(Any One) **Paper-M501(i)-(vi)** **Paper-(i):** Mechanics **Paper-(ii):** Probability and Statistics **Paper-(iii):** Numerical Methods **Paper- (iv):** Complex Variables **Paper-(v):** Linear Algebra **Paper-(vi):** Integral Transforms and Fourier Analysis
VI		(Any One) **Paper-M601(i)-(vii)** **Paper-(i):** Discrete Mathematics **Paper-(ii):** Linear Programming and Game Theory **Paper-(iii):** Tensors and Differential Geometry **Paper-(iv):** Number Theory **Paper-(v):** Advanced Mechanics **Paper-(vi):** Information Theory and Coding **Paper-(vii):** Special Theory of Relativity **Paper-(viii):** C++ Programming for Mathematics

Semester-I

Paper-M101: Calculus

Course Learning Outcomes: This course will enable the students to:

i) Calculate the limit and examine the continuity and understand the geometrical interpretation of differentiability.
ii) Understand the consequences of various mean value theorems.
iii) Draw curves in Cartesian and polar coordinate systems.
iv) Understand conceptual variations while advancing from one variable to several variables in calculus.
v) Inter-relationship amongst the line integral, double and triple integral formulations.
vi) Realize importance of Green, Gauss and Stokes' theorems in other branches of mathematics.

Unit-I: Sequences, Continuity and Differentiability

Notion of convergence of sequences and series of real numbers, ε-δ definition of limit and continuity of a real valued function; Differentiability and its geometrical interpretation; Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem and their geometrical interpretations, Darboux's theorem.

Unit-II: Expansion of Functions

Successive differentiation and Leibnitz theorem, Maclaurin's and Taylor's theorems for expansion of a function, Taylor's theorem in finite form with Lagrange, Cauchy and Roche–Schlömilch forms of remainder.

Unit-III: Curvature, Asymptotes and Curve Tracing

Curvature; Asymptotes of general algebraic curves, Parallel asymptotes, Asymptotes parallel to axes; Symmetry, Concavity and convexity, Points of inflection, Tangents at origin, Multiple points, Position and nature of double points; Tracing of Cartesian, polar and parametric curves; Envelopes and evolutes.

Unit-IV: Functions of Several Variables

Limit, continuity and first order partial derivatives, Higher order partial derivatives, Change of variables, Euler's theorem for homogeneous functions, Taylor's theorem, Total differentiation and Jacobians.

Unit-V: Double and Triple Integrals

Double integration over rectangular and nonrectangular regions, Double integrals in polar co-ordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals, Line integrals, Green's theorem, Area as a line integral, Surface integrals, Stokes' theorem, The Gauss divergence theorem.

References:

1. Howard Anton, I. Bivens & Stephan Davis (2016). *Calculus* (10th edition). Wiley India.
2. Gabriel Klambauer (1986). *Aspects of Calculus*. Springer-Verlag.
3. Wieslaw Krawcewicz & Bindhyachal Rai (2003). *Calculus with Maple Labs*. Narosa.
4. Gorakh Prasad (2016). *Differential Calculus* (19th edition). Pothishala Pvt. Ltd.
5. George B. Thomas Jr., Joel Hass, Christopher Heil & Maurice D. Weir (2018). *Thomas' Calculus* (14th edition). Pearson Education.
6. Jerrold Marsden, Anthony J. Tromba & Alan Weinstein (2009). *Basic Multivariable Calculus*, Springer India Pvt. Limited.
7. James Stewart (2012). *Multivariable Calculus* (7th edition). Brooks/Cole. Cengage.
8. Monty J. Strauss, Gerald L. Bradley & Karl J. Smith (2011). *Calculus* (3rd edition). Pearson Education. Dorling Kindersley (India) Pvt. Ltd.

Semester II

Paper-M201: Algebra

Course Learning Outcomes: This course will enable the students to:

i) Employ De Moivre's theorem in a number of applications to solve numerical problems.

ii) Learn about the fundamental concepts of groups, subgroups, normal subgroups, isomorphism theorems, cyclic and permutation groups.

iii) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix, using rank.

iv) Find eigenvalues and corresponding eigenvectors for a square matrix.

v) Understand real vector spaces, subspaces, basis, dimension and their properties.

Unit-I: Set Theory and Theory of Equations

Sets, Relations, Equivalence relations, Equivalence classes; Finite, countable and uncountable sets; The division algorithm, Divisibility and the Euclidean algorithm, Modular arithmetic and basic properties of congruences; Elementary theorems on the roots of polynomial equations, Imaginary roots, The fundamental theorem of algebra (statement only); The n^{th} roots of unity, De Moivre's theorem for integer and rational indices and its applications.

Unit-II: Groups, Subgroups, Normal Subgroups and Isomorphism Theorems

Definition and properties of a group, Abelian groups, Examples of groups including D_n (dihedral groups), Q_8 (quarternian group), $GL(n,\mathbb{R})$ (general linear groups) and $SL(n,\mathbb{R})$ (special linear groups); Subgroups and examples, Cosets and their properties, Lagrange's theorem and its applications, Normal subgroups and their properties, Simple groups, Factors groups; Group homomorphisms and isomorphisms with properties; First, second and third isomorphism theorems for groups.

Unit-III: Cyclic and Permutation Groups

Cyclic groups and properties, Classifications of subgroup of cyclic groups, Cauchy theorem for finite Abelian groups; Centralizer, Normalizer, Center of a group, Product of two subgroups, Permutation group and properties, Even and odd permutations, Cayley's theorem.

Unit-IV: Row Echelon Form of Matrices and Applications

Systems of linear equations, Row reduction and echelon forms, The rank of a matrix and its applications in solving system of linear equations; Matrix operations, Symmetric, skew-symmetric, self-adjoint, orthogonal, Hermition, skew-Hermition and unitary matrices; Determinant of a square matrix, The inverse of a square matrix, Eigenvectors and eigen values, The characteristic equation and the Cayley–Hamilton theorem, Applications of matrices to computer graphics and search engines.

Unit-V: Vector Spaces and Linear Transformations

Definitions of field and vector space with examples, Subspaces, Linear span, Quotient space and direct sum, Linearly independent and dependent sets, Bases and dimension, Linear transformation and matrix of a linear transformation, Change of coordinates, Rank and nullity of linear transformation, Rank-nullity theorem.

References:

1. Michael Artin (2014). *Algebra* (2nd edition). Pearson.
2. John B. Fraleigh (2007). *A First Course in Abstract Algebra* (7th edition). Pearson.
3. Stephen H. Friedberg, Arnold J.Insel& Lawrence E. Spence (2003). *Linear Algebra* (4thedition). Prentice-Hall of India Pvt. Ltd.
4. Joseph A. Gallian (2017). *Contemporary Abstract Algebra* (9th edition). Cengage.
5. Kenneth Hoffman & Ray Kunze (2015). *Linear Algebra* (2nd edition). Prentice-Hall.
6. I. N. Herstein (2006). *Topics in Algebra* (2nd edition). Wiley India.
7. Nathan Jacobson (2009). *Basic Algebra* I (2nd edition). Dover Publications.
8. Ramji Lal (2017). *Algebra 1: Groups, Rings, Fields and Arithmetic*. Springer.
9. I.S. Luthar & I.B.S. Passi (2013). *Algebra: Volume 1: Groups.* Narosa.

Semester-III

Paper-M301: Differential Equations

Course Learning Outcomes: The course will enable the students to:

i) Understand the genesis of ordinary as well as partial differential equations.

ii) Learn various techniques of getting exact solutions of certain solvable first order differential equations and linear differential equations of second order.

iii) Know Picard's method of obtaining successive approximations of solutions of first order ordinary differential equations, passing through a given point in the plane.

iv) Learn about solution of first order linear partial differential equations using Lagrange's method.

v) Know how to solve second order linear partial differential equations with constant coefficients.

vi) Formulate mathematical models in the form of ordinary and partial differential equations to problems arising in physical, chemical and biological disciplines.

Unit-I: First Order Differential Equations

Basic concepts and genesis of ordinary differential equations, Order and degree of a differential equation, Differential equations of first order and first degree, Equations in which variables are separable, Homogeneous equations, Linear differential equations and equations reducible to linear form, Exact differential equations, Integrating factor, First order higher degree equations solvable for x, y and p, Clairaut's form and singular solutions; Picard's method of successive approximations and the statement of Picard's theorem for the existence and uniqueness of the solutions of the first order differential equations.

Unit-II: Second Order Linear Differential Equations

Statement of existence and uniqueness theorem for the solution of linear differential equations, General theory of linear differential equations of second order with variable coefficients, Solutions of homogeneous linear ordinary differential equations of second order with constant coefficients, Method of variation of parameters and method of undetermined coefficients, Reduction of order, Euler-Cauchy equations, Coupled linear differential equations with constant coefficients.

Unit-III: First Order Partial Differential Equations

Genesis of Partial differential equations (PDE), Concept of linear and non-linear PDEs, Methods of solution of Simultaneous differential equations of the form: $dx/P(x,y,z) = dy/Q(x,y,z) = dz/R(x,y,z)$, Lagrange's method for PDEs of the form: $P(x,y,z)p+Q(x,y,z)q=R(x,y,z)$, where $p=\partial z/\partial x$ and $q=\partial z/\partial y$; Solutions passing through a given curve.

Unit-IV: Second Order Partial Differential Equations with Constant Coefficients

Principle of superposition for homogeneous linear PDEs, Relation between solution sets of non-homogeneous linear PDEs and their corresponding homogeneous equations, Reducible and irreducible homogeneous equations and their solutions in various possible cases, Solution of non-homogeneous reducible equations using Lagrange's method for first order equations.

Unit-V: Applications

Orthogonal trajectories of one-parameter families of curves in a plane, Minimum velocity of escape from Earth's gravitational field, Newton's law of cooling, Malthusian and logistic population models, Radioactive decay, Free and forced mechanical oscillations of a spring suspended vertically carrying a mass at its lowest tip, Phenomena of resonance, LCR circuits, Surfaces orthogonal to a given system of surfaces.

References:

1. Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10th edition). J. Wiley & Sons
2. B. Rai & D. P. Choudhury (2006). *Ordinary Differential Equations - An Introduction*. Narosa Publishing House Pvt. Ltd. New Delhi.
3. Shepley L. Ross (2007). *Differential Equations* (3rd edition). Wiley.
4. George F. Simmons (2017). *Differential Equations with Applications and Historical Notes* (3rd edition). CRC Press. Taylor & Francis.
5. Ian N. Sneddon (2006). *Elements of Partial Differential Equations*. Dover Publications.

Semester IV

Paper- M401 Real Analysis

Course Learning Outcomes: This course will enable the students to:

i) Understand basic properties of real number system such as least upper bound property and Order property.
ii) Realize importance of bounded, convergent, Cauchy and monotonic sequences of real numbers, find their limit superior and limit inferior.
iii) Apply various tests to determine convergence and absolute convergence of a series of real numbers.
iv) Learn about Riemann integrability of bounded functions and algebra of R-integrable functions.
v) Determine various applications of the fundamental theorem of integral calculus.
vi) Relate concepts of uniform continuity, differentiation, integration and uniform convergence.

Unit-I: Real Numbers

The set of real numbers ($\mathbb{R}$) as an ordered field, Least upper bound properties of $\mathbb{R}$, Metric property and completeness of $\mathbb{R}$, Archimedean property of $\mathbb{R}$, Dense subsets of $\mathbb{R}$, Nested intervals property; Neighborhood of a point in $\mathbb{R}$, Open sets, limit point of a set, closed and perfect sets in $\mathbb{R}$, connected and compact subsets of $\mathbb{R}$, Heine-Borel theorem.

Unit-II: Convergence of Sequences in $\mathbb{R}$

Bounded and monotonic sequences, Convergent sequence and its limit, Limit theorems, Monotone convergence theorem, Subsequences, Bolzano–Weierstrass theorem, Limit superior and limit inferior, Cauchy sequence, Cauchy's convergence criterion.

Unit-III: Infinite Series

Convergence of a series of positive real numbers, Necessary condition for convergence, Cauchy criterion for convergence; Tests for convergence: Comparison test, Limit comparison test, D'Alembert's ratio test, Cauchy's n^{th} root test, Abel's test, Integral test; Alternating series, Absolute and conditional convergence, Leibniz theorem, Rearrangements of series, Riemann's rearrangement theorem.

Unit-IV: Riemann Integration

Riemann integrability of bounded functions, Examples of R-integrable and non-integrable functions, Algebra of Riemann integrable functions, Integrability of continuous and monotonic functions, Darboux theorems, Fundamental theorem of integral calculus, First mean value theorem and second mean value theorems (Bonnet and Weierstrass forms). Necessary and sufficient condition for Riemann integrable function (Statement only).

Unit-V: Uniform Convergence, Continuity and Improper Integrals

Pointwise and uniform convergence of sequence and series of functions, Uniform continuity, Weierstrass's M-test, Uniform convergence and continuity, Uniform convergence and differentiability, Improper integrals and tests for improper integrals, Beta and Gamma functions.

References:

1. T. M. Apostol (2008). *Mathematical Analysis: A Modern Approach to Advanced Calculus*. Pearson Education.
2. Charalambos D. Aliprantis &) Owen Burkinshaw1998). *Principles of Real Analysis* (3rd edition). Academic Press.
3. Robert G. Bartle & Donald R. Sherbert (2015). *Introduction to Real Analysis* (4th edition).Wiley India.
4. Gerald G. Bilodeau, Paul R. Thie & G. E. Keough (2015). *An Introduction to Analysis* (2nd edition), Jones and Bartlett India Pvt. Ltd.
5. E. Hewitt & K. Stromberg (2013). *Real and Abstract Analysis.* Springer-Verlag.
6. K. A. Ross (2013). *Elementary Analysis*: *The Theory of Calculus* (2nd edition). Springer.
7. Walter Rudin. *Principles of Mathematical Analysis* (3rd edition), Tata McGraw Hill.

Semester V

Electives (Any one)

Paper-M501

Paper-(i): Mechanics

Course Learning Outcomes: This course will enable the students to:

i) Familiarize with subject matter, which has been the single centre, to which were drawn mathematicians, physicists, astronomers and engineers together.

ii) Understand necessary conditions for the equilibrium of particles acted upon by various forces and learn the principle of virtual work for a system of coplanar forces acting on a particle.

iii) Determine the centre of gravity of materialistic systems and discuss the equilibrium of a uniform cable hanging freely under its own weight.

iv) Deal with the kinematics and kinetics of the rectilinear and planar motions of a particle including the constrained oscillatory motions of particles.

v) Learn that a particle moving under a central force describes a plane curve and know the Kepler's laws of the planetary motions, which were deduced by him long before the mathematical theory given by Newton.

Unit-I: Statics

Coplanar forces, Couples, Moment of force and a couple about a point and a line, Equilibrium of a particle and of a system of particles; Work and potential energy, Principle of virtual work for a system of coplanar forces acting on a particle, Forces which can be omitted in forming the equations of virtual work.

Unit-II: Centre of Gravity and Common Catenary

Concepts of Centre of mass and Centre of gravity, Centre of gravity of an uniform arc, plane area and solids of revolution; Common catenary, Approximations of a catenary.

Unit-III: Rectilinear Motion

Simple harmonic motion and its geometrical representation, Motion under inverse square law, Motion in resisting media, Concept of terminal velocity, Motion of varying mass.

Unit-IV: Motion in a Plane

Kinematics and kinetics of motion, Expressions for velocity and acceleration in Cartesian, polar and intrinsic coordinates; Motion in a vertical circle, projectile and cycloidal motion.

Unit-V: Central Orbits

Equation of motion under a central force, Differential equation of an orbit, (p, r) equation of an orbit, Apses and apsidal distances, Areal velocity, Characteristics of central orbits, Kepler's laws of planetary motion.

References:

1. R. S. Varma (1962). *A Text Book of Statics*. Pothishala Pvt. Ltd.
2. P.L. Srivastava (1964). *Elementary Dynamics*. Ram Narain Lal, Beni Prasad Publishers Allahabad.
3. J. L. Synge & B. A. Griffith (1949). *Principles of Mechanics*. McGraw-Hill.
4. S.L. Loney (2006). *An Elementary Treatise on the Dynamics of a Particle and of Rigid Bodies*. Read Books.
5. A. S. Ramsey (2009). *Statics*. Cambridge University Press.
6. A. S. Ramsey (2009). *Dynamics*. Cambridge University Press.

Paper-(ii): Probability and Statistics

Course Learning Outcomes: This course will enable the students to:

i) Understand the basic concepts of probability.

ii) Appreciate the importance of probability distribution of random variables and to know the notion of central tendency.

iii) Establish the joint distribution of two random variables in terms their correlation and regression.

iv) Understand central limit theorem which shows that the empirical frequencies of so many natural populations exhibit normal distribution.

v) Study entropy and information theory in the framework of probabilistic models.

Unit-I: Probability and Random Variables

Axiomatic and empirical definitions of probability, Independent and dependent events, Conditional probability and Baye's theorem; Discrete and continuous random variables and their probability distributions, Cumulative distribution function, n^{th} Moments, Moment generating function, Characteristic function.

Unit-II: Univariate Distributions

Discrete distributions**:** Bernoulli trials and Bernoulli distribution, Binomial and Poisson distributions; Continuous distributions**:** Uniform, Geometric, Gamma, Exponential, Chi-square, Beta and normal distributions; Normal approximation to the binomial distribution, Central limit theorem.

Unit-III: Bivariate Distribution

Joint cumulative distribution function and its properties, Joint probability density function, Marginal distributions, Expectation of function of two random variables, Joint moment generating function, Conditional distributions and expectations, Independence of bivariate random variables.

Unit-IV: Correlation and Regression

The Correlation coefficient, Covariance, Calculation of covariance from joint moment generating function, Linear regression for two variables, The method of least squares, Bivariate normal distribution, Markov theorem, Chebyshev's theorem, Weak and strong laws of large numbers.

Unit-V: Information Theory

Uncertainty, Information and entropy, Conditional and joint entropy, Uniform Priors, Polya's urn model and random graphs, Applications of random graphs.

References:

1. David Applebaum (1996). *Probability and Information: An Integrated Approach.* Cambridge University Press.
2. Robert V. Hogg, Joseph W. McKean & Allen T. Craig (2013). *Introduction to Mathematical Statistics* (7th edition), Pearson Education.
3. Irwin Miller & Marylees Miller (2014). *John E. Freund's Mathematical Statistics with Applications* (8th edition). Pearson. Dorling Kindersley Pvt. Ltd. India.
4. Jim Pitman (1993). *Probability*, Springer-Verlag.
5. Sheldon M. Ross (2014). *Introduction to Probability Models* (11th edition). Elsevier.
6. A. M. Yaglom and I. M. Yaglom (1983). *Probability and Information*. D. Reidel Publishing Company. Distributed by Hindustan Publishing Corporation (India) Delhi.

Paper-(iii): Numerical Methods

Course Learning Outcomes: This course will enable the students to:

i) Obtain numerical solutions of algebraic and transcendental equations.

ii) Find numerical solutions of system of linear equations and to check the accuracy of the solutions.

iii) Learn about various interpolating and extrapolating methods to find numerical solutions.

iv) Solve initial and boundary value problems in differential equations using numerical methods.

v) Apply various numerical methods in real life problems.

Unit-I: Numerical Methods for Solving Algebraic and Transcendental Equations

Round-off error and computer arithmetic, Local and global truncation errors, Algorithms and convergence; Bisection method, false position method, fixed point iteration method, Newton's method and secant method for solving equations.

Unit-II: Numerical Methods for Solving Linear Systems

Partial and scaled partial pivoting, LU decomposition and its applications, Thomas method for tridiagonal systems; Gauss–Jacobi, Gauss–Seidel and successive over-relaxation (SOR) methods.

Unit-III: Interpolation

Lagrange and Newton interpolations, Piecewise linear interpolation, Cubic spline interpolation, Finite difference operators, Gregory–Newton forward and backward difference interpolations.

Unit-IV: Numerical Differentiation and Integration

First order and higher order approximation for first derivative, Approximation for second derivative; Numerical integration: Trapezoidal rule, Simpson's rule and its error analysis, Bulirsch–Stoer extrapolation methods, Richardson extrapolation.

Unit-V: Initial and Boundary Value Problems of Differential Equations

Euler’s method, Runge–Kuttamethods, Higher order one step method, Multi-step methods; Finite difference method, Shooting method, Real life examples: Google search engine, 1D and 2D simulations, Weather forecasting.

References:

1. Brian Bradie (2006), *A Friendly Introduction to Numerical Analysis.* Pearson.
2. C. F. Gerald & P. O. Wheatley (2008). *Applied Numerical Analysis* (7th edition), Pearson Education, India.
3. M.K. Jain, S. R. K. Iyengar & R. K. Jain (2012). *Numerical Methods for Scientific and Engineering Computation* (6th edition). New Age International Publishers.
4. Robert J. Schilling & Sandra L. Harris (1999). *Applied Numerical Methods for Engineers Using* MATLAB *and C*. Thomson-Brooks/Cole.

Paper- (iv): Complex Variables

Course Learning Outcomes: This course will enable the students to:

i) Visualize complex numbers as points of $\mathbb{R}^2$, stereographic projection of complex plane on the Riemann sphere and various geometric properties of linear fractional transformations.

ii) Understand the significance of differentiability and analyticity of complex functions leading to the Cauchy–Riemann equations.

iii) Learn the role of Cauchy–Goursat theorem and Cauchy integral formula in evaluation of contour integrals.

iv) Apply Liouville's theorem in fundamental theorem of algebra.

v) Understand the convergence, term by term integration and differentiation of a power series.

vi) Learn Taylor and Laurent series expansions of analytic functions; classify the nature of singularities, poles and residues and application of Cauchy Residue theorem.

Unit-I: Complex Plane

Complex numbers and their representation, algebra of complex numbers; Complex plane, Open set, Domain and region in complex plane; Stereographic projection and Riemann sphere, Complex functions and their limits including limit at infinity; Continuity, Möbius transformations and their geometrical properties.

Unit-II: Analytic Functions and Cauchy–Riemann Equations

Complex functions and their limits including limit at infinity; Continuity, differentiability and analyticity; Cauchy–Riemann equations, Harmonic functions, Sufficient conditions for differentiability and analyticity, Analyticity and zeros of exponential, trigonometric and logarithmic functions; Branch cut and branch of multi-valued functions.

Unit-III: Cauchy's Theorems and Fundamental Theorem of Algebra

Line integral, Path independence, Complex integration, Green's theorem, Anti-derivative theorem, Cauchy–Goursat theorem, Cauchy integral formula, Cauchy's inequality, Derivative of analytic function, Liouville's theorem, Fundamental theorem of algebra, Maximum modulus theorem and its consequences.

Unit-IV: Power Series

Sequences, series and their convergence, Taylor series and Laurent series of analytic functions, Power series, Radius of convergence, Integration and differentiation of power series, Absolute and uniform convergence of power series.

Unit-V: Singularities and Contour Integration

Zeros and poles of meromorphic functions, Nature of singularities, Picard's theorem, Residues, Cauchy's residue theorem, Argument principle, Rouche's theorem, Jordan's lemma, Evaluation of proper and improper integrals.

References:

1. Lars V. Ahlfors (2017). *Complex Analysis* (3rd edition). McGraw-Hill Education.
2. Joseph Bak & Donald J. Newman (2010). *Complex Analysis* (3rd edition). Springer.
3. James Ward Brown & Ruel V. Churchill (2009). *Complex Variables and Applications* (9th edition). McGraw-Hill Education.
4. John B. Conway (1973). *Functions of One Complex Variable*. Springer-Verlag.
5. E.T. Copson (1970). *Introduction to Theory of Functions of Complex Variable*. Oxford University Press.
6. Theodore W. Gamelin (2001). *Complex Analysis*. Springer-Verlag.
7. George Polya & Gordon Latta (1974). Complex Variables. Wiley.
8. H. A. Priestley (2003). Introduction to Complex Analysis. Oxford University Press.
9. E. C. Titchmarsh (1976). Theory of Functions (2nd edition). Oxford University Press.

Paper-(v): Linear Algebra

Course Learning Outcomes: This course will enable the students to:

i) Learn about properties of linear transformation and isomorphism theorems.
ii) Understand the concept of polynomials and their prime factorization.
iii) Find canonical form of linear transformations.
iv) Obtain various variants of diagonalisation of linear transformations.
v) Apply Cauchy-Schwarz inequality for deriving metric on inner product spaces and obtain orthonormal basis using Gram-Schmidt orthogonalisation.

Unit-I: Properties of Linear Transformation

Vector spaces, Linearly independent and dependent sets, Bases and dimension, Linear transformation, Linear functional, Dual spaces and second dual space, Transpose of linear transformation, Algebra of linear transformations, Isomorphism theorems.

Unit-II: Polynomials

Algebras, The algebra of polynomials, Lagrange interpolation, Vandermonde matrix, Polynomial ideals, Taylor's formula, The prime factorization of a polynomial, Algebraically closed fields.

Unit-III: Elementary Cannonical Forms

Determinant functions, Characteristic values of a linear transformation, Cayley-Hamilton theorem for linear transformations, Annihilating polynomials, Invariant subspaces, Minimal and characteristic polynomials.

Unit-IV: Diagonalisation and Jordan Cannonical Form

Diagonalisability of linear transformations, Direct sum decomposition, Invariant direct sums, The primary decomposition theorem, Triangular form, Jordan canonical form, trace and transpose.

Unit-V: Inner Product Spaces

Definition and examples of inner product space, orthogonality, Cauchy-Schwarz inequality, Gram-Schmidt orthogonalisation, Diagonalisation of symmetric matrices, Hermitian, Unitary and normal operators.

References:

1. Stephen H.Friedberg, Arnold J.Insel& Lawrence E. Spence (2003). *Linear Algebra* (4thedition). Prentice-Hall of India Pvt. Ltd.

2. I. M. Gel'fand (1989). *Lectures on Linear Algebra*. Dover Publications.
3. Kenneth Hoffman & Ray Kunze (2015). *Linear Algebra* (2nd edition). Prentice-Hall.
4. Nathan Jacobson (2009). *Basic Algebra* I (2nd edition). Dover Publications.
5. Nathan Jacobson (2009). *Basic Algebra* II (2nd edition). Dover Publications.
6. Serge Lang (2005). *Introduction to Linear Algebra* (2nd edition). Springer India.
7. Gilbert Strang (2014). *Linear Algebra and its Applications* (2ndedition). Elsevier.

Paper-(vi): Integral Transforms and Fourier Analysis

Course Learning Outcomes: This course will enable the students to:

i) Know about piecewise continuous functions, Dirac delta function, Laplace transforms and its properties.

ii) Solve ordinary differential equations using Laplace transforms.

iii) Familiarise with Fourier transforms of functions belonging to $L^1(\mathbb{R})$ class, relation between Laplace and Fourier transforms.

iv) Explain Parseval's identity, Plancherel's theorem and applications of Fourier transforms to boundary value problems.

v) Learn Fourier series, Bessel's inequality, term by term differentiation and integration of Fourier series.

Unit-I: Laplace Transforms

Integral transform, Kernel of an integral transform, Reduction of integral transform into Laplace transform, Linearity, Existence theorem, Laplace transforms of derivatives and integrals, Shifting theorems, Change of scale property, Laplace transforms of periodic functions, Dirac's delta function.

Unit-II: Further Properties of Laplace Transforms and Applications

Differentiation and integration of transforms, Convolution theorem, Integral equations, Inverse Laplace transform, Lerch's theorem, Linearity property of inverse Laplace transform, Translations theorems of inverse Laplace transform, Inverse transform of derivatives, Applications of Laplace transform in obtaining solutions of ordinary differential equations and integral equations.

Unit-III: Fourier Transforms

Fourier and inverse Fourier transforms, Fourier sine and cosine transforms, Inverse Fourier sine and cosine transforms, Linearity property, Change of scale property, Shifting property, Modulation theorem, Relation between Fourier and Laplace transforms.

Unit-IV: Solution of Equations by Fourier Transforms

Solution of integral equation by Fourier sine and cosine transforms, Convolution theorem for Fourier transform, Parseval's identity for Fourier transform, Plancherel's theorem, Fourier transform of derivatives, Applications of infinite Fourier transforms to boundary value problems, Finite Fourier transform, Inversion formula for finite Fourier transforms.

Unit-V: Fourier Series

Fourier cosine and sine series, Fourier series, Differentiation and integration of Fourier series, Absolute and uniform convergence of Fourier series, Bessel's inequality, The complex form of Fourier series.

References:

1. James Ward Brown & Ruel V. Churchill (2011). F*ourier Series and Boundary Value Problems*. McGraw-Hill Education.
2. Charles K. Chui (1992). *An Introduction to Wavelets*. Academic Press.
3. Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10^{th} edition). Wiley.
4. Walter Rudin (2017). *Fourier Analysis on Groups*. Dover Publications.
5. A. Zygmund (2002). *Trigonometric Series* (3^{rd} edition). Cambridge University Press.

Semester VI

Electives (Any one)

Paper – M601

Paper-(i): Discrete Mathematics

Course Learning Outcomes: This course will enable the students to:

i) Learn about partially ordered sets, lattices and their types.

ii) Understand Boolean algebra and Boolean functions, logic gates, switching circuits and their applications.

iii) Solve real-life problems using finite-state and Turing machines.

iv) Assimilate various graph theoretic concepts and familiarize with their applications.

Unit-I: Partially Ordered Sets

Definitions, examples and basic properties of partially ordered sets (poset), Order isomorphism, Hasse diagrams, Dual of a poset, Duality principle, Maximal and minimal elements, Least upper bound and greatest upper bound, Building new poset, Maps between posets.

Unit-II: Lattices

Lattices asposets, Lattices as algebraic structures, Sublattices, Products and homomorphisms; Definitions, examples and properties of modular and distributive lattices; Complemented, relatively complemented and sectionally complemented lattices.

Unit-III: Boolean Algebras and Switching Circuits

Boolean algebras, De Morgan's laws, Boolean homomorphism, Representation theorem; Boolean polynomials, Boolean polynomial functions, Disjunctive and conjunctive normal forms, Minimal forms of Boolean polynomials, Quine–McCluskeymethod, Karnaugh diagrams, Switching circuits and applications.

Unit-IV: Finite-State and Turing Machines

Finite-state machines with outputs, and with no output; Deterministic and nodeterministic finite-state automaton; Turing machines: Definition, examples, and computations.

Unit-V: Graphs

Definition, examples and basic properties of graphs, Königsberg bridge problem; Subgraphs, Pseudographs, Complete graphs, Bipartite graphs, Isomorphism of graphs, Paths and circuits, Eulerian circuits, Hamiltonian cycles, Adjacency matrix, Weighted graph, Travelling-salesman problem, Shortest path, Dijkstra’s algorithm.

References:

1. B. A. Davey & H. A. Priestley (2002). *Introduction to Lattices and Order* (2nd edition). Cambridge University Press.
2. Edgar G. Goodaire& Michael M. Parmenter (2018). *Discrete Mathematics with Graph Theory* (3rd edition). Pearson Education.
3. Rudolf Lidl & Günter Pilz (1998). *Applied Abstract Algebra* (2nd edition). Springer.
4. Kenneth H. Rosen (2012). *Discrete Mathematics and its Applications*: *With Combinatorics and Graph Theory* (7th edition). McGraw-Hill.
5. C. L. Liu (1985). *Elements of Discrete Mathematics* (2nd edition). McGraw-Hill.

Paper-(ii): Linear Programming and Game Theory

Course Learning Outcomes: This course will enable the students to:

i) Analyze and solve linear programming models of real life situations.
ii) Provide graphical solution of linear programming problems with two variables, and illustrate the concept of convex set and extreme points.
iii) Solve linear programming problems using simplex method.
iv) Learn techniques to solve transportation and assignment problems.
v) Solve two-person zero sum game problems.

Unit-I: Linear Programming Problem, Convexity and Basic Feasible Solutions

Formulation and examples**,** Canonical and Standard forms, Graphical solution, Convex and polyhedral sets, Extreme points, Basic solutions, Basic Feasible Solutions, Correspondence between basic feasible solutions and extreme points.

Unit-II: Simplex Method

Optimality criterion, Improving a basic feasible solution, Unboundedness; Simplex algorithm and its tableau format; Artificial variables, Two-phase method, Big-M method.

Unit-III: Duality

Formulation of the dual problem, Duality theorems, Unbounded and infeasible solutions in the primal, Solving the primal problem using duality theory.

Unit-IV: Transportation and Assignment Problems

Formulation of transportation problems, Methods of finding initial basic feasible solutions: North-west corner rule, Least cost method, Vogel approximation method, Algorithm for obtaining optimal solution; Formulation of assignment problems, Hungarian method.

Unit-V: Game Theory

Formulation of two-person zero-sum games, Games with mixed strategies, Graphical method for solving matrix game, Dominance principle, Solution of game problem, Linear programming method of solving a game.

References:

1. Mokhtar S. Bazaraa, John J. Jarvis & Hanif D. Sherali (2010). *Linear Programming and Network Flows* (4^{th} edition). John Wiley & Sons.
2. G. Hadley (2002). *Linear Programming*. Narosa Publishing House.

3. Frederick S. Hillier & Gerald J. Lieberman (2015). *Introduction to Operations Research* (10th edition). McGraw-Hill Education.
4. Hamdy A. Taha (2017). *Operations Research*: *An Introduction* (10th edition). Pearson.
5. Paul R. Thie & Gerard E. Keough (2014). *An Introduction to Linear Programming and Game Theory* (3rd edition). Wiley India Pvt. Ltd.

Paper-(iii): Tensors and Differential Geometry

Course Learning Outcomes: This course will enable the students to:

i) Explain the basic concepts of tensors.
ii) Understand role of tensors in differential geometry.
iii) Learn various properties of curves including Frenet–Serret formulae and their applications.
iv) Know the Interpretation of the curvature tensor, Geodesic curvature, Gauss and Weingarten formulae.
v) Understand the role of Gauss's Theorema Egregium and its consequences.
vi) Apply problem-solving with differential geometry to diverse situations in physics, engineering and in other mathematical contexts.

Unit-I: Tensors

Contravariant and covariant vectors, Transformation formulae, Tensor product of two vector spaces, Tensor of type (r, s), Symmetric and skew-symmetric properties, Contraction of tensors, Quotient law, Inner product of vectors.

Unit-II: Further Properties of Tensors

Fundamental tensors, Associated covariant and contravariant vectors, Inclination of two vectors and orthogonal vectors, Christoffel symbols, Law of transformation of Christoffel symbols, Covariant derivatives of covariant and contravariant vectors, Covariant differentiation of tensors, Curvature tensor, Ricci tensor, Curvature tensor identities.

Unit-III: Curves in $\mathbb{R}^2$ and $\mathbb{R}^3$

Basic definitions and examples, Arc length, Curvature and the Frenet–Serret formulae, Fundamental existence and uniqueness theorem for curves, Non-unit speed curves.

Unit-IV: Surfaces in $\mathbb{R}^3$

Basic definitions and examples, The first fundamental form, Arc length of curves on surfaces, Normal curvature, Geodesic curvature, Gauss and Weingarten formulae, Geodesics, Parallel vector fields along a curve and parallelism.

Unit-V: Geometry of Surfaces

The second fundamental form and the Weingarten map; Principal, Gauss and mean curvatures; Isometries of surfaces, Gauss's Theorema Egregium, The fundamental theorem of surfaces, Surfaces of constant Gauss curvature, Exponential map, Gauss lemma, Geodesic coordinates, The Gauss–Bonnet formula and theorem.

References:

1. Christian Bär (2010). *Elementary Differential Geometry*. Cambridge University Press.
2. Manfredo P. do Carmo (2016). *Differential Geometry of Curves & Surfaces* (Revised and updated 2nd edition). Dover Publications.
3. Alferd Gray (2018). *Modern Differential Geometry of Curves and Surfaces with Mathematica* (4th edition). Chapman & Hall/CRC Press, Taylor & Francis.
4. Richard S. Millman & George D. Parkar (1977). *Elements of Differential Geometry*. Prentice-Hall.
5. R. S. Mishra (1965). *A Course in Tensors with Applications to Riemannian Geometry*. Pothishala Pvt. Ltd.
6. Sebastián Montiel & Antonio Ross (2009). *Curves and Surfaces*. American Mathematical Society.

Paper-(iv): Number Theory

Course Learning Outcomes: This course will enable the students to learn:

i) Some of the open problems related to prime numbers, viz., Goldbach conjecture etc.
ii) About number theoretic functions and modular arithmetic.
iii) Public crypto systems, in particular, RSA.

Unit-I: Distribution of Primes and Theory of Congruencies

Linear Diophantine equation, Prime counting function, Prime number theorem, Goldbach conjecture, Fermat and Mersenne primes, Congruence relation and its properties, Linear congruence and Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.

Unit-II: Number Theoretic Functions

Number theoretic functions for sum and number of divisors, Multiplicative function, The Mobius inversion formula, The greatest integer function. Euler's phi-function and properties, Euler's theorem.

Unit-III: Primitive Roots

The order of an integer modulo *n*, Primitive roots for primes, Composite numbers having primitive roots; Definition of quadratic residue of an odd prime, and Euler's criterion.

Unit-IV: Quadratic Reciprocity Law and Public Key Encryption

The Legendre symbol and its properties, Quadratic reciprocity, Quadratic congruencies with composite moduli.

Unit-V: Applications

Public key encryption, RSA encryption and decryption, Some important application.

References:

1. David M. Burton (2007). *Elementary Number Theory* (7th edition). McGraw-Hill.
2. Gareth A. Jones & J. Mary Jones (2005). *Elementary Number Theo*ry. Springer.
3. Neville Robbins (2007). *Beginning Number Theory* (2nd edition). Narosa.

Paper-(v): Advanced Mechanics

Course Learning Outcomes: This course will enable the students to:

i) Understand the reduction of force system in three dimensions to a resultant force acting at a base point and a resultant couple.

ii) Learn about a nul point, a nul line, and a nul plane with respect to a system of forces acting on a rigid body together with the idea of central axis.

iii) Know the inertia constants for a rigid body and the equation of momental ellipsoid together with the idea of principal axes and principal moments of inertia to derive Euler's dynamical equations.

iv) Study the kinematics and kinetics of fluid motions to understand the equation of continuity in Cartesian, cylindrical polar and spherical polar coordinates which are used to derive Euler's equations and Bernoulli's equation.

v) Deal with two-dimensional fluid motion using the complex potential and also to understand the concepts of sources, sinks, doublets and the image systems of these with regard to a line and a circle.

Unit-I: Statics in Space

Forces in three dimensions, Reduction to a force and a couple, Equilibrium of a system of particles, Central axis and Wrench, Equation of the central axis, Nul points, nul lines and nul planes with respect to a given system of forces.

Unit-II: Motion of a Rigid Body

Definition of rigid body as a system of particles and condition of rigidity, Moments and products of inertia of standard bodies, Momental ellipsoid, Principal axes and principal moments of inertia; The momentum of a rigid body in terms of linear momentum and angular momentum about any point, Equations of motion in terms of linear and angular momenta, Motion of a rigid body with a fixed point, Existence of an angular velocity, Kinetic energy and angular momentum of a rigid body in terms of inertia constants, Euler's dynamical equations and the motion under no forces.

Unit-III: Kinematics of Fluid Motion

Lagrangian and Eulerian approaches, Acceleration of fluid at a point, Equation of continuity in Cartesian, cylindrical polar and spherical polar coordinates, Boundary surface, Streamlines and path lines, Velocity potential, Rotational and irrotational motion, Vorticity vector and vortex lines.

Unit-IV: Kinetics of Fluid Motion

Euler's equations of motion in Cartesian, cylindrical polar and spherical polar coordinates, Bernoulli's equation, Impulsive motion.

Unit-V: Motion in Two-Dimensions

Stream function, Complex potential, Basic singularities: Sources, sinks, doublets and complex potentials due to these basic singularities; Image system of a simple source and a simple doublet with regard to a line and a circle.

References:

1. A. S. Ramsay (1960). *A Treatise on Hydromechanics, Part-II Hydrodynamics* G. Bell & Sons.
2. F. Chorlton (1967). *A Textbook of Fluid Dynamics*. CBS Publishers.
3. Michel Rieutord (2015). *Fluid Dynamics An Introduction.* Springer.
4. E. A. Milne (1965). *Vectorial Mechanics*,Methuen & Co.Limited.London.
5. F. Chorlton (1969). *A Text Book of Dynamics*, D Van Nosterand Co. Ltd.London.

Paper-(vi): Information Theory and Coding

Course Learning Outcomes: This course will enable the students to:

i) Study simple ideal statistical communication models.
ii) Understand the development of codes for transmission and detection of information.
iii) Learn about the input and output of a signal via transmission channel.
iv) Study detection and correction of errors during transmission.
v) Represent a linear code by matrices - encoding and decoding.

Unit-I: Concepts of Information Theory

Communication processes, A model of communication system, A quantitative measure of information, Binary unit of information, A measure of uncertainty, H function as a measure of uncertainty, Sources and binary sources, Measure of information for two-dimensional discrete finite probability schemes.

Unit-II: Entropy Function

A sketch of communication network, Entropy, Basic relationship among different entropies, A measure of mutual information, Interpretation of Shannon's fundamental inequalities; Redundancy, efficiency, and channel capacity; Binary symmetric channel, Binary erasure channel, Uniqueness of the entropy function, Joint entropy and conditional entropy, Relative entropy and mutual information, Chain rules for entropy, Conditional relative entropy and conditional mutual information, Jensen's inequality and its characterizations, The log sum inequality and its applications.

Unit-III: Concepts of Coding

Block codes, Hamming distance, Maximum likelihood decoding, Levels of error handling, Error correction, Error detection, Erasure correction, Construction of finite fields, Linear codes, Matrix representation of linear codes, Hamming codes.

Unit-IV: Bounds of Codes

Orthogonality relation, Encoding and decoding of linear codes, The singleton bound and maximum distance separable codes, The sphere-packing bound and perfect codes, The Gilbert–Varshamov bound, MacWilliams' identities.

Unit-V: Cyclic Codes

Definition and examples of cyclic codes, Generator polynomial and check polynomial, Generator matrix and check matrix, Bose–Chaudhuri–Hocquenghem (BCH) code as a cyclic code.

References:

1. Robert B. Ash, (2014). *Information Theory*. Dover Publications.
2. Thomas M. Cover & Joy A. Thomas (2013). *Elements of Information Theory* (2nd edition). Wiley India Pvt. Ltd.
3. Joseph A. Gallian (2017). *Contemporary Abstract Algebra* (9th edition), Cengage.
4. Fazlollah M. Reza, (2003). *An Introduction to Information Theory*. Dover Publications.
5. Ron M. Roth (2007). *Introduction to Coding Theory*. Cambridge University Press.
6. Claude E. Shannon & Warren Weaver (1969). *The Mathematical Theory of Communication*. The University of Illinios Press.

Paper-(vii): Special Theory of Relativity

Course Learning Outcomes: This course will enable the students to:

i) Understand the basic elements of Newtonian mechanics including Michelson–Morley experiment and geometrical interpretations of Lorentz transformation equations.
ii) Learn about length contraction, time dilation and Lorentz contraction factor.
iii) Study 4-dimensional Minkowskian space-time and its consequences.
iv) Understand equations of motion as a part of relativistic mechanics.
v) Imbibe connections between relativistic mechanics and electromagnetism.

Unit-I: Newtonian Mechanics

Inertial frames, Speed of light and Gallilean relativity, Michelson–Morley experiment, Lorentz–Fitzgerold contraction hypothesis, Relative character of space and time, Postulates of special theory of relativity, Lorentz transformation equations and its geometrical interpretation, Group properties of Lorentz transformations.

Unit-II: Relativistic Kinematics

Composition of parallel velocities, Length contraction, Time dilation, Transformation equations for components of velocity and acceleration of a particle and Lorentz contraction factor.

Unit-III: Geometrical representation of space-time

Four dimensional Minkowskian space-time of special relativity, Time-like, light-like and space-like intervals, Null cone, Proper time, World line of a particle, Four vectors and tensors in Minkowiskian space-time.

Unit-IV: Relativistic Mechanics

Variation of mass with velocity. Equivalence of mass and energy. Transformation equations for mass momentum and energy. Energy-momentum four vector. Relativistic force and Transformation equations for its components. Relativistic equations of motion of a particle.

Unit-V: Electromagnetism

Transformation equations for the densities of electric charge and current. Transformation equations for electric and magnetic field strengths. The Field of a Uniformly Moving Point charge. Forces and fields near a current carrying wire. Forces between moving charges. The invariance of Maxwell`s equations.

References:

1. James L. Anderson (1973). *Principles of Relativity Physics*. Academic Press.
2. Peter Gabriel Bergmann (1976). *Introduction to the Theory of Relativity*. Dover Publications.
3. C. Moller (1972). *The Theory of Relativity* (2nd edition). Oxford University Press.
4. Robert Resnick (2007). *Introduction to Special Relativity*. Wiley.
5. Wolfgang Rindler (1977). *Essential Relativity: Special, General, and Cosmological*. Springer-Verlag.
6. V. A. Ugarov (1979). *Special Theory of Relativity*. Mir Publishers, Moscow.

Paper-(viii): C++ Programming for Mathematics

Course Learning Outcomes: This course will enable the students to:

i) Understand and apply the programming concepts of C++ for solving mathematical problems.
ii) Apply to find greatest common divisors, generate random numbers, understand Cartesian geometry and algebraic concepts through programming.
iii) Represent the outputs of programs visually in terms of well formatted text and plots.

Course Contents:

Unit 1: Essentials of C++

Basics of programming, C++ as a general purpose programming language, Structure of a C++ program, Common compilers and IDE's, Basic data-types, Variables and literals in C++, Operators, Expressions, Evaluation precedence, Type compatibility, Debugging and testing; Finding greatest common divisor, Random number generation.

Unit 2: Structured Data

Structured data-types in C++, Arrays and manipulating data in arrays, Factorization of an integer, Compute Euler's totient; Objects and classes**:** Information hiding, Modularity, Constructors and destructors, Methods, Polymorphism; Cartesian geometry using points (2 & 3-dimensional), Pythagorean triples.

Unit 3: Containers and Templates

Containers and Template Libraries**:** Sets, Iterators, Multisets, Vectors, Maps, Lists, Stacks, Queues; Basic set algebra, Modulo arithmetic, Permutations, and Polynomials.

Unit 4: Mathematical Libraries and Packages

Arbitrary precision arithmetic using the GMP package; Two-dimensional arrays in C++ with applications in finding eigenvalues, eigenvectors, rank, nullity, and solving system of linear equations in matrices; Features of C++ for input/output and visualization**,** Strings, Streams, Formatting methods, Processing files in a batch, Command-line arguments, Visualization packages and their use in plots.

Unit-V: Odds and Ends

Runtime errors and graceful degradation, Robustness in a program; Exception handling: Try-catch and throw; Defining and deploying suitable exception handlers in programs; Compiler options; Conditional compilation; Understanding and defining suitable pragmas;

Identification and description of install parameters of mathematical libraries, debugging installation, working with multiple libraries simultaneously and maintaining correctness and consistency of data.

References:

1. Nell Dale & Chip Weems (2013).*Programming and Problem Solving with C++* (6th edition). Jones & Bartlett Learning.
2. Peter Gottschling (2016). *Discovering Modern C++*: *An Intensive Course for Scientists, Engineers, and Programmers*. Pearson.
3. Nicolai M. Josuttis (2012). *The C++ Standard Library*: *A Tutorial and Reference* (2nd edition). Addison-Wesley, Pearson.
4. Donald E. Knuth (1968). *The Art of Computer Programming.* Addison-Wesley.
5. Edward Scheinerman (2006). *C++ for Mathematicians*: *An Introduction for Students and Professionals*. Chapman & Hall/CRC. Taylor & Francis.
6. B. Stroustrup (2013). *The C++ Programming Language* (4th edition). Addison-Wesley.

6.3. References for each course

References for each course are given at the end of course contents of each course.

7. Teaching-Learning Process

The teaching-learning process should be aimed at systematic exposition of basic concepts so as to acquire knowledge of mathematics in a canonical manner. In this context, applications of mathematics and linkage with the theory constitute a vital aspect of the teaching-learning process. The course offers many modes of learning and assessment. Students have great freedom of choice of subjects which they can study. The various components of teaching-learning process are summarized in the following heads.

1. **Lectures:** The most common method of imparting knowledge is through lectures. There are diverse modes of delivering lectures such as through blackboard, power point presentation and other technology aided means. A judicious mix of these means is a key aspect of teaching-learning process.

2. **Tutorials:** Assimilating mathematical ideas, deepening understanding, and gaining mastery of new concepts all take time, commitment, and intelligent effort. To reinforce learning, to monitor progress, and to provide a regular pattern of study, tutorials are essential requirements. During these tutorials, difficulties faced by the students in understanding the lectures, are dealt with. Tutorials are also aimed at solving problems associated with the concepts discussed during the lectures.

3. **Practicals:** To give a geometrical visualisation and obtaining numerical solutions of mathematical problems, various Computer Algebra Systems (CAS) are used in practical sessions. These sessions provide vital insights into mathematical concepts and draw learner's attention towards limitations of numerical computations. During practicals, mathematical models arising in real life problems can also be simulated.

4. **Options System:** LOCF in mathematics provides great flexibility both in terms of variety of courses and range of references in each course. In fifth and sixth semesters students can opt for elective courses from a wide range of pure and applied courses, depending on their interests and requirements.

5. **Field based learning:** Students may enhance their knowledge through field based learning while understanding the practical importance of mathematics especially in industries.

6. **Prescribed textbooks:** A large number of books are included in the list of references of each course for enrichment and enhancement of knowledge.

7. **E-learning resources:** Learner may also access electronic resources and educational websites for better understanding and updating the concepts.

8. **Self-study materials:** Self-study material provided by the teachers/instructors is an integral part of learning mathematics. It helps in bridging the gaps in the classroom teaching. It also provides scope for teachers to give additional information beyond classroom learning.

9. **Open-ended projects:** Home assignments at regular intervals and project work involving applications of theory are necessary to assimilate basic concepts of mathematics. Hence, it is incumbent on the part of a learner to complete open-ended projects assigned by the teacher.

10. **Internships:** The teaching-learning process needs to be further supported by other activities devoted to subject-specific and interdisciplinary skills, summer and winter internships in mathematics. During these internships it is expected that a learner will interact with experts and write a report on a topic provided to the learner.

11. **Institute visits:** Institute visit by a learner is also a part of learning process. During such visits a learner has access to knowledge by attending academic activities such as seminars, colloquia, library consultation and discussion with faculty members. These activities provide guidance and direction for further study.

12. **Industrial visits:** Industrial visits offer an opportunity to observe real time applications of mathematical concepts. These visits also give an opportunity to realise the power of mathematical ideas and their translation in problem solving.

13. **Training programmes:** Training programmes such as Mathematics Training and Talent Search (MTTS) program, organised by various agencies/institutes like National Board for Higher Mathematics, also provide an opportunity to learn various dimensions of mathematics.

8. Assessment Methods

A range of assessment methods which are appropriate to test the understanding of various concepts of mathematics will be used. Priority will be given to formative assessment. Various learning outcomes will be assessed using time-bound examinations, series of open and closed book tests with uniform distribution over time, problem solving, home assignments, individual and group project reports, seminar presentations, viva-voce examination, participation in mathematical quizzes/competitions at local, regional, national and international levels and participations in internship programs. For various courses in mathematics, the following assessment methods shall be adopted:

i. Announced/unannounced quizzes
ii. Scheduled/unscheduled tests
iii. Problem solving sessions aligned with classroom lectures
iv. Practical assignments
v. Regular chamber consultation with faculty members
vi. Periodic tests, mid semester examination and semester end comprehensive examination
vii. Seminar presentations
viii. Computer skill test and computer simulation of concepts learnt
ix. Awareness tests of historical development of mathematical ideas
x. Awareness tests of recent advances in mathematics
xi. Awareness tests of various national/international prizes in mathematics including Fields Medal, Abel prize, Rolf Nevanlinna Prize, Srinivasa Ramanujan Medal etc. and the work of recipients of these prizes
xii. Awareness test of applications of mathematics in other branches of science, technology and other disciplines.

9. Keywords

LOCF, CBCS, Course Learning Outcomes, Employability, Simulation, Graduate Attributes Communication Skills, Critical Thinking, Descriptors.

Expert Committee Members of Learning Outcomes based Curriculum Framework (LOCF) Mathematics

Prof. Shyam Lal, Department of Mathematics, Institute of Science, Banaras Hindu University, Varanasi

Prof. (Mrs.) C. S. Lalitha, Department of Mathematics, University of Delhi, Delhi.

Prof. R. P. Sharma, Department of Mathematics, Himachal Pradesh University, Shimla.

Co-opted Members:

Prof. B. Rai (Retd.), Department of Mathematics, University of Allahabad, Allahabad.

Prof. Khalil Ahmad (Retd.), Department of Mathematics, Jamia Millia Islamia, New Delhi.

Prof. Harish Chandra, Department of Mathematics, Institute of Science, Banaras Hindu University, Varanasi.

Learning Outcomes based Curriculum Framework (LOCF)

for

MICROBIOLOGY

Undergraduate Programme

2019

ज्ञान-विज्ञान विमुक्तये

UNIVERSITY GRANTS COMMISSION

BAHADUR SHAH ZAFAR MARG

NEW DELHI – 110 002

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.

DPSingh

New Delhi
30th July, 2019

(Prof. D. P. Singh)
Chairman
University Grants Commission

Table of Contents

Preamble

Microbiology is the study of microorganisms or microbes such bacteria, viruses, fungi, algae, cyanobacteria, protozoa and prions. They are extremely important as their diverse activities range from causation of deadly diseases in humans, animals and plants to production of highly useful products like antibiotics, enzymes, alcohol, fermented foods, and recycling of dead and decaying organic matter in the nature. Thus the science of microbiology has an important role to play in health, agriculture, environment and industry. Several discoveries in the last two to three decades, which significantly impact these area have put Microbiology on the centre stage of teaching, research and development all over the globe.

The Choice Based Credit System (CBCS) curriculum for Microbiology at the undergraduate level has now been developed into a new system called Learning Outcome Curriculum Framework (LOCF) under the recommendations and guidance of University Grants Commission (UGC). The LOCF approach first envisioned the programme learning outcomes of the B.Sc. (Hons) program in Microbiology as well as the learning outcomes of the courses being taught under this programme, keeping in view the graduate attributes of the subject. The curriculum was then developed in tune with the learning outcomes. It is envisaged that the students trained under this curriculum will have the required attributes of knowledge, skills, temperament and ethics related to the subject of Microbiology. Besides the contents of the curriculum, the teaching learning processes have also been designed to achieve these attributes. A variety of learning assessment tasks have been included in the curriculum. Besides assessing the knowledge/skills acquired by the students, these tasks would also help to supplement the teaching learning processes.

There are 14 core courses (CC1 - 14) which encompass all important aspects of the discipline of Microbiology and are all compulsory courses. The choice based Discipline Specific Elective (DSE) courses are designed to enhance the expanse of the subject. DSE also give the students a chance to apply their knowledge of microbiology to study societal problems and suggest solutions in the form of small project under the mentorship of their teachers. These are also designed to expose the students to leaders / innovators in the areas related to microbiology for inspiration. The Generic Elective Courses (GEC) are designed to impart comprehensive understanding of Microbiology to students from other disciplines. The Microbiology students will have the choice to select courses from other disciplines depending on their interest and passion besides Microbiology. The CC, DSE and GEC are all 6 credit (4 Credit Theory and 2 Credit Laboratory work) courses. A number of Skill based Elective Courses (SEC), 4 Credits each would give the students option to develop skills in areas which have direct relevance to employability in diagnostics, health, food and pharmaceutical industries, agriculture and environment-related job opportunities in Microbiology. The focus of the Ability Enhancement Compulsory Courses (AECC) which are 2 Credits each, is to develop communication skills and awareness about our environment. To comply with the education policy of Govt. of India namely access, equity and quality we have included Online Courses (OLC) which are available on NPTEL or SWAYAM portals under MOOCS programme being developed by MHRD to provide opportunity to the most disadvantaged students and to bridge the digital divide. The online courses would also inculcate the habit of self-study at their own pace by the students and also acclimatize them to future technologies of learning processes.

1. Introduction:

In the increasingly globalized society, it is important that the younger generation especially the students are equipped with knowledge, skills, mindsets and behaviors which may enable them to perform their duties in a manner so that they become important contributors to the development of the society. This will also help them to fully utilize their educational training for earning a decent living so that the overall standard of their families and surroundings improve leading to development of welfare human societies. To achieve this goal, it is imperative that their educational training is improved such that it incorporates the use of newer technologies, use of newer assessment tools for mid-course corrections to make sure that they become competitive individuals to shoulder newer social responsibilities and are capable of undertaking novel innovations in their areas of expertise. In the face of the developing knowledge society, they are well aware about the resources of self-development using on-line resources of learning which is going to be a major component of learning in the future. The learning should also be a continuous process so that the students are able to re-skill themselves so as to make themselves relevant to the changing needs of the society. In the face of this need, the educational curricula, teaching learning processes, training, assessment methods all need to be improved or even re-invented. The higher educational institutions (HEI) all over the globe are in the grip of this urgent task and India needs to keep pace with all these developments.

2. Learning Outcomes based approach to Curriculum Planning:

Learning Outcome based approach to curriculum planning (LOCF) is almost a paradigm shift in the whole gamut of higher education such that it is based on first and foremost identifying the outcomes of the learning required for a particular subject of study, and then planning all components of higher education so as to achieve these outcomes. The learning outcomes are the focal point of the reference to which all planning and evaluation of the end learning is compared and further modifications are made to fully optimize the education of the individuals in a particular subject. For the subject of Microbiology the outcomes are defined in terms of the understanding and knowledge of the students in microbiology and the practical skills the students are required to have to be competitive microbiologist so that they are able to play their role as microbiologist wherever required in the society such as the diseases caused by the microbes, their diagnosis and remedies; the role of microbiologists in the biotechnology industry and how they may be able to fit the bill in the industry. The students are also trained in such a way that they develop critical thinking and problem solving as related to the microbiology. The curriculum developed and the teaching and the evaluation tasks are such that the students are able to apply their knowledge and training of microbiology to solve the problems of microbiology as these exist or appear from time to time in the society. The curriculum envisions that the student, once graduate as specialists in a discipline, have an important role to play in the newer developments and innovations in the future in the subject for advancement of the discipline.

2.1 Nature and extent of the B.Sc. Programme:

The undergraduate programme in Microbiology is the first level of college or university degree in the country as in several other parts of the world. After obtaining this degree, a microbiologist may enter into the job market or opt for undertaking further higher studies in the subject. After graduation the students may join industry, academia, public health and play their role as microbiologists in a useful manner contributing their role in the development of the welfare society. Thus the undergraduate level degree in microbiology must prepare the students for all these objectives. Thus the LOCF curriculum developed has a very wide range covering all aspects of Microbiology with reasonable depth of knowledge and skills so to as to diversify them in various specialties of the subject and play their role professionally as expected of them. It is also imperative that microbiologists are evaluated in a manner appropriate to assess their proper development as microbiologists. The current LOCF in Microbiology has been designed in keeping all these important points in mind.

2.2 Aims of Bachelor's degree programme in MICROBIOLOGY:

The aim of the undergraduate degree in Microbiology is to make students knowledgeable about the various basic concepts in a wide ranging contexts which involve the use of knowledge and skills of Microbiology. Their understanding, knowledge and skills in Microbiology needs to be developed through a thorough teaching learning processes in the class, practical skills through the laboratory work, their presentation and articulation skills, exposure to industry and interaction with industry experts, write short research-based projects where they are guided and mentored by the academic and other experts of the subject.

3. Graduate Attributes in Microbiology:

As mentioned earlier B.Sc. degree in Microbiology is the first college/university level degree in the country as in several parts of the world. The students graduating in this degree must have through understanding of basic knowledge or understanding of the fundamentals of Microbiology as applicable to wide ranging contexts. They should have the appropriate skills of Microbiology so as to perform their duties as microbiologists. They must be able to analyze the problems related to microbiology and come up with most suitable solutions. As microbiology is an interdisciplinary subject the students might have to take inputs from other ares of expertise. So the students must develop the spirit of team work. Microbiology is a very dynamic subject and practitioners might have to face several newer problems. To this end, the microbiologists must be trained to be innovative to solve such newer problems. Several newer developments are taking place in microbiology. The students are trained to pick up leads and see the possibility of converting these into products through entrepreneurship. To this end, the students are made to interact with industry experts so that they may able to see the possibility of their transition into entrepreneurs. They are also made aware of the requirements of developing a Microbiology enterprise by having knowledge of patents, copyrights and various regulatory process to make their efforts a success.

Besides attaining the attributes related to the profession of Microbiology, the graduates in this discipline should also develop ethical awareness which is mandatory for practicing a scientific discipline including ethics of working in a laboratory work and ethics followed for scientific publishing of their research work in future. The students graduating in microbiology should also develop excellent communication skills both in the written as well as spoken language which are must for them to pursue higher studies from some of the best and internationally acclaimed universities and research institutions spread across the globe.

4. Qualification Descriptors:

The following may serve as the important qualification descriptors for a UG degree in Microbiology:

1. Knowledge of the diverse places where microbiology is involved.
2. Understanding of diverse Microbiological processes.
3. Basic skills such as culturing microbes, maintaining microbes, safety issues related to handling of microbes, Good Microbiological practices etc.
4. Moderately advanced skills in working with microbes such as pilot scale culturing, downstream processes, diagnostics etc.
5. Generation of new knowledge through small research projects
6. Ability to participate in team work through small microbiology projects.
7. Ability to present and articulate their knowledge of Microbiology.
8. Knowledge of recent developments in the area of Microbiology.
9. Analysis of data collected through study and small projects.
10. Ability to innovate so as to generate new knowledge.
11. Awareness how some microbiology leads may be developed into enterprise.
12. Awareness of requirements for fruition of a microbiology-related enterprise.

5. Programme Learning Outcomes of B.Sc. Hons Microbiology course:

A candidate who is conferred an UG (Hons) degree i.e. B.Sc. (Hons) degree in microbiology needs to have acquired/developed following competencies during the programme of the study:

1. Acquired knowledge and understanding of the microbiology concepts as applicable to diverse areas such as medical, industrial, environment, genetics, agriculture, food and others.

2. Demonstrate key practical skills/competencies in working with microbes for study and use in the laboratory as well as outside, including the use of good microbiological practices.
3. Competent enough to use microbiology knowledge and skills to analyze problems involving microbes, articulate these with peers/ team members/ other stake holders, and undertake remedial measures/ studies etc.
4. Developed a broader perspective of the discipline of Microbiology to enable him to identify challenging societal problems and plan his professional career to develop innovative solutions for such problems.

6. Structure of B.Sc. Hons Microbiology course

Semester	Core Courses (CC)	Discipline Specific Elective (DSE)	Generic Elective (GEC)	Skill Enhancement Course (SEC)	Ability Enhancement Compulsory Course (AECC)	Total Marks & Credits
Semester I	2 PAPERS T(4x2=8) P(2x2=4) Total =12	1 PAPER T(4x1=4) P(2x1=2) Total =6	NIL	NIL	1 PAPER T(4x1=4) Total =4	400 Marks (22 Credits)
Semester II	2 PAPERS T (4x2=8) P(2x2=4) Total =12	1 PAPER T(4x1=4) P(2x1=2) Total =6	NIL	NIL	1 PAPER T(4x1=4) Total =4	400 Marks (22 Credits)
Semester III	2 PAPERS T (4x2=8) P(2x2=4) Total =12	1 PAPER T(4x1=4) P(2x1=2) Total =6	1 PAPER T(4x1=4) P(2x1=2) Total =6	NIL	NIL	400 Marks (24 Credits)
Semester IV	2 PAPERS T (4x2=8) P(2x2=4) Total =12	1 PAPER T(4x1=4) P(2x1=2) Total =6	1 PAPER T(4x1=4) P(2x1=2) Total =6	NIL	NIL	400 Marks (24 Credits)
Semester V	3 PAPERS T (4x3=12) P(2x3=6) Total =18	NIL	1 PAPER T(4x1=4) P(2x1=2)	1 PAPER T(4x1=4) Total =4	NIL	500 Marks (28 Credits)

			Total =6			
Semester VI	3 PAPERS T (4x3=12) P(2x3=6) Total =18	NIL	1 PAPER T(4x1=4) P(2x1=2) Total =6	1 PAPER T(4x1=4) Total =4	NIL	500 Marks (28 Credits)
Sem. I – VI Each paper of 100 marks	14 PAPERS 1400Marks	4 PAPERS 400Marks	4 PAPERS 400Marks	2 PAPERS 200Marks	2PAPERS 200Marks	2600 Marks (148 Credits)

FOR B. Sc. MICROBIOLOGY (Without Honors)	12 PAPERS 1200Marks (48+24=72)	4 PAPERS 400Marks (16+8=24)	4 PAPERS 400Marks (16+8=24)	2 PAPERS 200Marks (8)	2 PAPERS 200Marks (8)	2400Marks (136 Credits)

T = Theory**; P =** Practical or Lab work**.**

Numbers in parentheses indicate the credits of the course.

Students can opt *any two* on-line courses available on MOOCS through SWAYAM / NPTEL) in lieu of any two of the above courses.

Course credits:

CC, DSE & GEC - Each course is of 6 credits(4 Credits of Theory + 2 Credits of Lab Work)

AECC & SEC – Each course is of 4 credits.

Each course is of 100 Marks

<u>Distributions of Marks within each Paper except Skill-Based Courses*:</u>

Each Paper Per semester : 100 Marks (Theory: 75 Marks + Lab. Course: 25 Marks) Theory Paper : 75 Marks (Internal assessment: 15 + Term end Exam: 60)

Internal assessment : Average of 2 best performances out of 3 tests would be considered

2 Test examinations and 1 assignment: 15 marks of each

***Skill-Based Course : 100 Marks**

Theory: 25 Marks and Lab. / Field work: 75 Marks

- **Internal assessment: 15 + Term end Exam:60**

PATTERN OF QUESTION PAPER

SEMESTER END EXAMINATION

- The paper comprises five Units containing one question of 12marks from each unit.
- All five questions are compulsory with internal choice within each question.
- Each question will comprise

  [a] 2 objective type questions (1 mark each),

  [b] 2 short answer questions (2 marks each)and

  [c] 6 conceptual type questions (6 marks each). Of these questions 30% questions would be analytical questions (problem solving type).
- Maximum up to 40% of the question paper's content may be repeated in next examination.

Details of the Courses
CORE COURSES (CC)
CC1: Microbial World and Principles of Microbiology
CC2: Bacteriology and Systematics
CC3: Basic Biochemistry
CC4: Microbial techniques & Instruments
CC5: Virology
CC6: Mycology & Phycology
CC7: Cell and Molecular Biology
CC8: Microbial Genetics
CC9: Microbial Physiology and Metabolism
CC10: Environmental Microbiology and Microbial Ecology
CC11: Industrial Microbiology
CC12: Medical and Veterinary Microbiology, and Immunology
CC13: Agriculture, Food and Dairy Microbiology
CC14:Advanced Microbiology

ABILITY ENHANCEMENT COMPULSORY (AECC) COURSES
AECC1: Environmental Science
AECC2: Communication Skills (English/MIL)

DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)
DSE 1: Biophysics, Biomathematics & Biostatistics
DSE 2: Basic Computer & Bioinformatics
DSE 3: Microbial Biotechnology
DSE 4: Hereditary and Evolution
DSE 5: Biosafety and Intellectual Property Rights
DSE 6: Plant Pathology & Disease Management
DSE 7: Pharmaceutical Microbiology

DSE 8: Advanced Instrumentation: Principles and Applications
DSE 9: Project Work on Microbiology of Societal Importance
DSE 10: Veterinary Microbiology

GENERIC ELECTIVE COURSE (GEC): Any Four
GEC1: Microbial World and Microbial Diversity
GEC2: Bacteriology and Virology
GEC3: Medical Microbiology and Immunology
GEC4: Industrial and Food Microbiology
GEC5: Microbes in Sustainable Agriculture and Development
GEC6: Microbial Enzyme Technology
GEC7: Microbial Genetics and Molecular Biology
GEC8: Genetic Engineering and Biotechnology

SKILL ENHANCEMENT COURSE (SEC): Any Two
SEC1: Microbial Quality Control in Food & Pharmaceutical Industries
SEC2: Microbial Diagnostics and Public Health
SEC3: Human Microbial Disease Management
SEC4: Mushroom Cultivation Technology
SEC5: Food Fermentation Technology
SEC6: Microbial Products (e. g. Antibiotics, Bio-fertilizers, Biofuels, Bio-pesticides, Vaccines etc.)
SEC7: Microbiological Analysis of Air, Water & Soil
SEC8: Interactions with Entrepreneurs in Microbial Biotechnology and Startups

***ON LINE COURSE (OLC):Any Two from MOOCS (NPTEL/SWAYAM)**
OLC 1: Applied Environmental Microbiology (NPTEL)
OLC 2: Biochemistry (NPTEL)
OLC 3: Fundamentals of Microbiology (NPTEL)
OLC 4: Food Microbiology and Food Safety (SWAYAM)
OLC 5: Industrial Microbiology (SWAYAM)

Course Learning Outcomes

&

Contents of the Courses

CORE COURSES (CC)

CC1: Microbial World and Principles of Microbiology

Course learning outcomes: At the conclusion of this course the students -

Outcome 1. Have developed a good knowledge of the development of the discipline of Microbiology and the contributions made by prominent scientists in this field.

Outcome 2. Have developed a very good understanding of the characteristics of different types of microorganisms, methods to organize/classify these into and basic tools to study these in the laboratory.

Outcome 3. Are able to explain the useful and harmful activities of the microorganisms.

Outcome 4. Are able to perform basic experiments to grow and study microorganisms in the laboratory.

THEORY COURSE
(4 Credits)

Unit – 1:	History of microbiology and introduction to the microbial world. Germ theory of disease, Development of various microbiological techniques and golden era of microbiology. Contributions of Antony von Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Alexander Fleming, Martinus W. Beijerinck, Sergei N. Winogradsky, Selman A. Waksman, Paul Ehrlich, Elie Metchnikoff and Edward	**15 Lectures**

	Jenner.	
Unit – 2:	Physiochemical and biological characteristics of microorganisms (including viruses); Baltimore classification. Binomial Nomenclature, Whittaker's five kingdom and Carl Woese's three kingdom classification systems and their utility. General characteristics of Cellular microorganisms, wall-less forms - MLO (mycoplasma and spheroplasts) with emphasis on distribution and occurrence, morphology, mode of reproduction and economic importance.	**15 Lectures**
Unit – 3:	General concept of phytoplanktons and zooplanktons. General characteristics, structure, mode of reproduction and economic importance of actinomycetes with special reference to its application in medicine and industry. General characteristics, occurrence, structure, reproduction and importance of protozoa.	**15 Lectures**
Unit – 4:	Methods of studying microorganism; Staining techniques: simple staining, Gram staining, negative staining and acid-fast staining. Sterilization techniques (physical & chemical sterilization). Culture media & conditions for microbial growth. Pure culture isolation: Streaking, serial dilution and plating methods; cultivation, maintenance and preservation of pure cultures.	**10 Lectures**
Unit – 5:	Beneficial and harmful microbes and their role in daily life. Concept of disease in plant and animal caused by microorganism.	**5 Lectures**
LAB. COURSE (2 Credits)		
1. Microbiology Good Laboratory Practices and Bio-safety. 2. To study the principle and applications of important instruments (biological safety cabinets, autoclave, incubator, BOD incubator, hot air oven, light microscope, pH		

meter) used in the microbiology laboratory.

3. Preparation of culture media (liquid & solid) for bacterial cultivation.
4. Handling and care of laboratory equipment - autoclave, hot air oven, incubator, and laminar airflow.
5. Sterilization of media using autoclave and assessment of sterility.
6. Sterilization of glassware using hot air oven.
7. Sterilization of heat sensitive material by membrane filtration.
8. Demonstration of the presence of microflora in the environment by exposing nutrient agar plates to air.
9. Observation of microorganisms - bacteria, cyanobacteria protozoa, fungi, yeasts, and algae from natural habitats.
10. Study of common fungi, algae and protozoan using temporary / permanent mounts.

Reference Books

11. Prescot, M.J., Harley, J.P. and Klein, D.A. Microbiology. 5th Edition WCB Mc Graw Hill, New York, (2002).

1. Tortora, G.J., Funke, B.R. and Case, C.L. Microbiology: An Introduction. Pearson Education, Singapore, (2004).
2. Alcomo, I.E. Fundamentals of Microbiology. VI Edition, Jones and Bartlett Publishers. Sudbury. Massachusetts, (2001).
3. Black J.G.Microbiology-Principlesand Explorations.JohnWiley&SonsInc.NewYork, (2002).
4. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
5. Willey,Sherwood,Woolverton. Prescott,Harley, and Klein's Microbiology McGraw-Hill publication
6. Tortora,Funke,Case. Microbiology.Pearson Benjamin Cummings.
7. JACQUELYN G. BLACK. Microbiology Principles and explorations. JOHN WILEY & SONS, INC.
8. Madigan,Martinko, Bender,Buckley,Stahl.Brock Biology of Microorganisms. Pearson
9. Tom Besty,D.C Jim Koegh.Microbiology Demystified McGRAW-HILL.

<table>
<tr><td colspan="3">CC2: Bacteriology and Systematics</td></tr>
<tr><td colspan="3">Course learning outcomes: At the completion of this course, the students are able to -
Outcome 1. Describe characteristics of bacterial cells, cell organelles, cell wall composition and various appendages like capsules, flagella or pili.
Outcome 2. Differentiate a large number of common bacteria by their salient characteristics; classify bacteria into groups.
Outcome 3. Describe the nutritional requirements of bacteria for growth; developed knowledge and understanding that besides common bacteria there are several other microbes which grow under extreme environments.
Outcome 4. Perform basic laboratory experiments to study microorganisms; methods to preserve bacteria in the laboratory; calculate generation time of growing bacteria.</td></tr>
<tr><td colspan="3">THEORY COURSE
(4 Credits)</td></tr>
<tr><td>Unit – 1</td><td>Cell size, shape and arrangement, capsule, flagella, fimbriae and pili.
Cell-wall: Composition and detailed structure of Gram-positive and Gram-negative cell walls, archaebacterial cell wall, Gram and acid-fast staining mechanisms, lipopolysaccharide (LPS), sphaeroplasts, protoplasts, and L-forms. Effect of antibiotics and enzymes on the cell wall.
Cell Membrane: Structure, function and chemical composition of bacterial and archaeal cell
membranes. Cytoplasm: Ribosomes, mesosomes, inclusion bodies, nucleoid. Endospore: Structure, formation, stages of sporulation.</td><td>12 Lectures</td></tr>
<tr><td>Unit – 2</td><td>Gram negative and Gram positive bacteria: characteristics and examples. Study of typical eubacteria (Bacillus, Clostridium, Staphylococcus, Streptococcus, Corynebacterium, Mycobacterium, Escherichia, Salmonella, Shigella, Vibrio, Helicobacter, Meningococcus, Spirochetes, Rickettsia, Mycoplasma and</td><td>12 Lectures</td></tr>
</table>

	Chlamydia.	
Unit – 3	Nutritional requirements in bacteria and nutritional categories. Culture media: components of media, natural and synthetic media, chemically defined media, complex media, selective, differential, enriched and enrichment media. Physical methods of microbial control: heat, low temperature, high pressure, filtration, desiccation, osmotic pressure, radiation. Chemical methods of microbial control: disinfectants, types and mode of action. Asexual methods of reproduction, logarithmic representation of bacterial populations, phases of growth, calculation of generation time and specific growth rate.	**12 Lectures**
Unit – 4	Aim and principles of classification, systematics and taxonomy, concept of species, taxa, strain; conventional, molecular and recent approaches to polyphasic bacterial taxonomy, evolutionary chronometers, rRNA oligonucleotide sequencing and its importance.. Differences between eubacteria and archaebacteria.	**12 Lectures**
Unit – 5	General characteristics, phylogenetic overview of archaebacteria. Introduction to Nanoarchaeota (*Nanoarchaeum*), Crenarchaeota (*Sulfolobus*, *Thermoproteus*) and Euryarchaeota [Methanogens (*Methanobacterium*, *Methanocaldococcus*), thermophiles (*Thermococcus*, *Pyrococcus*, *Thermoplasma*), and Halophiles (*Halobacterium*, *Halococcus*)].	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Preparation of different media: synthetic media, complex media- Nutrient agar, McConkey agar, EMB agar.
2. Simple staining
3. Negative staining
4. Gram staining
5. Acid fast staining – study using permanent slide.
6. Capsule staining
7. Endospore staining.
8. Isolation of pure cultures of bacteria by streaking method.
9. Preservation of bacterial cultures by various techniques.
10. Estimation of CFU count by spread plate method/pour plate method.
11. Motility by hanging drop method.

Reference Books

1. Prescott, M.J.,Harley,J.P.andKlein,D.A.Microbiology. 5th Edition WCB Mc GrawHill, New York, (2002).
2. Tortora, G.J., Funke ,B.R. and Case, C.L. Microbiology : An Introduction. Pearson Education, Singapore, (2004).
3. Alcomo,I.E.FundamentalsofMicrobiology.VIEdition, JonesandBartlettPublishers.Sudbury.Massachusetts, (2001).
4. Black J.G.Microbiology-Principlesand Explorations.JohnWiley&SonsInc.NewYork, (2002).
5. Tom Besty,D.C Jim Koegh.Microbiology Demystified McGRAW-HILL.

CC2: Bacteriology and Systematics

Course learning outcomes: At the completion of this course, the students are able to -

Outcome 1. Describe characteristics of bacterial cells, cell organelles, cell wall composition and various appendages like capsules, flagella or pili.

Outcome 2. Differentiate a large number of common bacteria by their salient characteristics; classify bacteria into groups.

Outcome 3. Describe the nutritional requirements of bacteria for growth; developed knowledge and understanding that besides common bacteria there are several other microbes which grow under extreme environments.

Outcome 4. Perform basic laboratory experiments to study microorganisms; methods to preserve bacteria in the laboratory; calculate generation time of growing bacteria.

THEORY COURSE
(4 Credits)

Unit – 1	Cell size, shape and arrangement, capsule, flagella, fimbriae and pili. Cell-wall: Composition and detailed structure of Gram-positive and Gram-negative cell walls, archaebacterial cell wall, Gram and acid-fast staining mechanisms, lipopolysaccharide (LPS), sphaeroplasts, protoplasts, and L-forms. Effect of antibiotics and enzymes on the cell wall. Cell Membrane: Structure, function and chemical composition of bacterial and archaeal cell membranes. Cytoplasm: Ribosomes, mesosomes, inclusion bodies, nucleoid. Endospore: Structure, formation, stages of sporulation.	**12 Lectures**
Unit – 2	Gram negative and Gram positive bacteria: characteristics and examples. Study of typical eubacteria (*Bacillus*, *Clostridium*, *Staphylococcus*, *Streptococcus*, *Corynebacterium*, *Mycobacterium*, *Escherichia*, *Salmonella*, *Shigella*, *Vibrio*, *Helicobacter*, *Meningococcus*, Spirochetes, *Rickettsia*, *Mycoplasma* and *Chlamydia*.	**12 Lectures**

Unit – 3	Nutritional requirements in bacteria and nutritional categories. Culture media: components of media, natural and synthetic media, chemically defined media, complex media, selective, differential, enriched and enrichment media. Physical methods of microbial control: heat, low temperature, high pressure, filtration, desiccation, osmotic pressure, radiation. Chemical methods of microbial control: disinfectants, types and mode of action. Asexual methods of reproduction, logarithmic representation of bacterial populations, phases of growth, calculation of generation time and specific growth rate.	**12 Lectures**
Unit – 4	Aim and principles of classification, systematics and taxonomy, concept of species, taxa, strain; conventional, molecular and recent approaches to polyphasic bacterial taxonomy, evolutionary chronometers, rRNA oligonucleotide sequencing and its importance.. Differences between eubacteria and archaebacteria.	**12 Lectures**
Unit – 5	General characteristics, phylogenetic overview of archaebacteria. Introduction to Nanoarchaeota (*Nanoarchaeum*), Crenarchaeota (*Sulfolobus*, *Thermoproteus*) and Euryarchaeota [Methanogens (*Methanobacterium*, *Methanocaldococcus*), thermophiles (*Thermococcus*, *Pyrococcus*, *Thermoplasma*), and Halophiles (*Halobacterium, Halococcus*)].	**12 Lectures**

LAB. COURSE
(2 Credits)

1. Preparation of different media: synthetic media, complex media- Nutrient agar, McConkey agar, EMB agar.
2. Simple staining
3. Negative staining
4. Gram staining
5. Acid fast staining – study using permanent slide.
6. Capsule staining
7. Endospore staining.
8. Isolation of pure cultures of bacteria by streaking method.
9. Preservation of bacterial cultures by various techniques.
10. Estimation of CFU count by spread plate method/pour plate method.
11. Motility by hanging drop method.

Reference Books

1. Prescott, M.J.,Harley,J.P.andKlein,D.A.Microbiology. 5th Edition WCB Mc GrawHill, New York, (2002).
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3. Alcomo,I.E.FundamentalsofMicrobiology.VIEdition, JonesandBartlettPublishers.Sudbury.Massachusetts, (2001).
4. Black J.G.Microbiology-Principlesand Explorations.JohnWiley&SonsInc.NewYork, (2002).
5. Tom Besty,D.C Jim Koegh.Microbiology Demystified McGRAW-HILL.

CC3: Basic Biochemistry

Course learning outcomes : By the end of this course the students-

Outcome 1. Developed a very good understanding of various biomolecules which are required for development and functioning of a bacterial cell.

Outcome 2. Have developed how the carbohydrates make the structural and functional components such as energy generation and as storage food molecules for the bacterial cells

Outcome 3. Well conversant about multifarious function of proteins; are able to calculate enzyme activity and other quantitative and qualitative parameters of enzyme kinetics; also knowledge about lipids and nucleic acids.

Outcome 4. Student are able to make buffers, study enzyme kinetics and calculate Vmax, Km, Kcat values.

THEORY COURSE

(4 Credits)

Unit – 1	Concept of bio-molecules - Building blocks of life, Macromolecules. Concept of Bioenergetics - First and second laws of Thermodynamics. Definitions of Gibb's Free Energy, enthalpy and Entropy and mathematical relationship among them, Standard free energy change and equilibrium constant Coupled reactions and additive nature of standard free energy change, Energy rich compounds, ATP, amino acids the building blocks of proteins. Titration curve of amino acid and its Significance, Classification, biochemical structure and notation of standard protein amino acids Ninhydrin reaction. General formula of amino acid and concept of zwitterion. Natural modifications of amino acids in proteins hydrolysine, cystine and hydroxyproline, Non protein amino acids: Gramicidin, beta-alanine, D-alanine and D-glutamic acid.	**12 Lectures**

Unit – 2	Carbohydrate: Families of monosaccharides – aldoses and ketoses, trioses, tetroses, pentoses, and hexoses. Stereo isomerism of monosaccharides, epimers, mutarotation and anomers of glucose. Furanose and pyranose forms of glucose and fructose, Haworth projection formulae for glucose; chair and boat forms of glucose, sugar derivatives, glucosamine. Disaccharides; concept of reducing and non-reducing sugars, occurrence and Haworth projections of maltose, lactose, and sucrose, polysaccharides, storage polysaccharides, starch and glycogen. Structural polysaccharides, cellulose, peptidoglycan and chitin	**12 Lectures**
Unit – 3	Protein: Primary, secondary, tertiary and quaternary structures. Enzymes: Structure of enzyme, Apoenzyme and cofactors, prosthetic group-TPP, coenzyme -NAD, metal cofactors, Classification of enzymes, Mechanism of action of enzymes: active site, transition state complex and activation energy. Lock and key hypothesis, and Induced Fit hypothesis. Significance of hyperbolic, double reciprocal plots of enzyme activity, Km, and allosteric mechanism Definitions of terms – enzyme unit, specific activity and turnover number, Effect of pH and temperature on enzyme activity. Enzyme inhibition: competitive- sulfa drugs; non-competitive-heavy metal salts.	**12 Lectures**
Unit – 4	Lipids: Definition and major classes of storage and structural lipids. Storage lipids. Fatty acids structure and functions. Essential fatty acids. Triacylglycerols structure, functions and properties. Saponification Structural lipids. Phosphoglycerides: Building blocks, general structure, functions and properties. Structure of phosphatidylethanolamine and phosphatidylcholine, Sphingolipids: building blocks, structure of sphingosine, ceramide. Special mention of sphingomyelins, cerebrosides and gangliosides Lipid functions: cell signals, cofactors, prostaglandins, Introduction to lipid micelles, monolayers, bilayers	**12 Lectures**
Unit – 5	Nucleic acids and vitamins. Biosynthesis of nucleotides. Base composition. A+T and G+C rich genomes. Structure and functions of DNA and RNA. Basic concept of nucleic acids protein interactions. Concept and types of vitamins and their role in metabolism.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Properties of water, concept of pH and buffers, preparation of buffers and Numerical problems to explain the concepts.
2. Numerical problems on calculations of Standard Free Energy Change and Equilibrium constant.
3. Standard Free Energy Change of coupled reactions.
4. Qualitative/Quantitative tests for carbohydrates, reducing sugars, non-reducing sugars.
5. Qualitative/Quantitative tests for lipids and proteins.
6. Study of protein secondary and tertiary structures with the help of models.
7. Study of enzyme kinetics – calculation of *V*max , Km, Kcat values.
8. Study effect of temperature, pH and heavy metals on enzyme activity.
9. Estimation of any one vitamin.

Reference Books

1. Tortora, G.J., Funke, B.R and Case, C.L. Microbiology: An Introduction. Pearson Education, Singapore, (2004).
2. Stanbury, Biochemistry
3. Voet.Fundamentals of biochemistry Wiley
4. M.M. Cox, D. L. Nelson.Lehninger's principles of biochemistry. W H Freeman
5. Stryer. Biochemistry W H Freeman

CC4: Microbial techniques & Instruments

Course learning outcomes: Major learning outcome of this course is that students develop a very good understanding of several microbiological techniques and instruments which are commonly used in a microbiology laboratory. The students have learnt-

Outcome 1. Principles which underlies sterilization of culture media, glassware and plastic ware to be used for microbiological work.

Outcome 2.Principles of a number of analytical instruments which the students have to use during the study and also later as microbiologists for performing various laboratory manipulations.

Outcome 3. Handling and use of microscopes for the study of microorganisms which are among the basic skills expected from a practicing microbiologist. They also get introduced a variety of modifications in the microscopes for specialized viewing.

Outcome 4. Several separation techniques which may be required to be handled later as microbiologists.

THEORY COURSE

(4 Credits)

Unit – 1:	Microbial techniques: Pure culture isolation: Streaking, serial dilution and plating methods; cultivation, maintenance and preservation/stocking of pure cultures; cultivation of anaerobic bacteria, and accessing non-culturable bacteria. Buffers in culture medium. Cultivation of fungi, actinomycetes, yeasts, algae. Cultivation of anaerobes.	**12 Lectures**
Unit – 2:	Sterilization, Disinfection, Antiseptic, Germicide, Sanitizer, Fungicide, Virucide, Bacteriostatic and Bactericidal agent. Chemical Disinfectants. Sterilization by Physical Agent, Heat: Moist Heat, Dry heat,Boiling,Tyndallization,Pasteurisation,Steamunderpressure(Autoclave),Incineration,Hot	**12 Lectures**

	air Oven. Radiations: Ionizing and Non-ionizing radiations. Inoculation and incubation, Principle and application of Laminar airflow.	
Unit – 3:	Microscopy**:** Principle, mechanism and application of photo optical instruments (different types of Microscopes), Phase contrast microscope, Bright Field Microscope, Dark Field Microscope, Phase Contrast Microscope, Fluoresence microscopy, Confocal microscopy, Scanning and Transmission Electron Microscopy. Micrometry. Principles of Centrifugation and Ultracentrifugation techniques and its applications.	**12 Lectures**
Unit – 4:	Chromatography: Principle and techniques with applications (Partition, adsorption, ion exchange, exclusion and affinity chromatography). Electrophoretic technique (agarose and polyacrylamide gel) its Components, working and applications	**12 Lectures**
Unit – 5:	Principle, mechanism and application of instruments used in Spectrophotometric techniques (UV and visible).Radiobiological techniques – characters of radioisotopes, autoradiography, Radioisotope dilution technique and pulse chase experiments. Basic principles & Law of absorption and radiation and its application.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Study of fluorescent micrographs to visualize bacterial cells.
2. Ray diagrams of phase contrast microscopy and Electron microscopy.
3. Separation of mixtures by paper / thin layer chromatography.
4. Demonstration of column packing in any form of column chromatography.
5. Separation of protein mixtures by any form of chromatography.
6. Separation of protein mixtures by Polyacrylamide Gel Electrophoresis (PAGE).
7. Determination of absorption max for an unknown sample and calculation of extinctioncoefficient.
8. Separation of components of a given mixture using a laboratory scale centrifuge.
9. Understanding density gradient centrifugation with the help of pictures.

Reference Books

1. Wilson& Walker.Principles andTechniquesinPractical Biochemistry. 5th Edition Cambridge University Press (2000).
2. MurphyD.B. FundamentalofLightMicroscopy&Electron Imaging.1st Edition.Wiley-Liss.(2001).
3. K L Ghatak. Techniques And Methods In Biology PHI Publication (2011)
4. Pranav Kumar. Fundamentals and Techniques of Biophysics and Molecular Biology (2016)
5. Aurora Blair. Laboratory Techniques & Experiments In Biology.Intelliz Press
6. D.T Plummer.An Introduction to Practical Biochemistry. McGraw Hill Publication 1987
7. Beckner, W.M., Kleinsmith L.J and Hardin J. The world of cell. IV edition Benjamin/Cummings (2000)
9.

CC5: Virology

Course learning outcomes: Students have-

Outcome 1. Understood what are viruses and the chemical nature of viruses, different types of viruses infecting animals, plants and bacteria (bacteriophages)

Outcome 2. Understanding about the biology of bacteriophages.

Outcome 3. Gained knowledge of a variety of plant viruses and animal viruses.

Outcome 4. The ability to describe role of viruses in the causation of the cancer'

THEORY COURSE

(4 Credits)

Unit – 1	Virology: Discovery of viruses, nature and definition of viruses, general properties, concept of viroids, virusoids, satellite viruses and Prions. Theories of viral origin; Structure of Viruses. Viral taxonomy-Classification and nomenclature of different groups of viruses. Baltimore system of classification.	**12 Lectures**
Unit – 2	Isolation, purification and cultivation of bacterial viruses. Study of one step growth curve of bacterial viruses. Types of bacteriophages, lytic and lysogenic phages (lambda phage) concept of early and late proteins, regulation of transcription in lambda phage. T even, T odd, ϕX174 and M13 phages.	**12 Lectures**
Unit – 3	Modes of viral transmission: Persistent, non- persistent, vertical and horizontal. Replication Assembly, maturation and release of viruses. Salient features of viral nucleic acid and the presence of unusual bases. Influenza and Hepatitis B virus, HIV, polio virus, Vaccinia virus, Rabies Virus. TMV, Cauliflower Mosaic Virus.	**12 Lectures**

Unit – 4	Introduction to oncogenic viruses. Types of oncogenic DNA and RNA viruses: Concepts of oncogenes and proto-oncogenes.	**12 Lectures**
Unit – 5	Antiviral compounds and their mode of action Interferon and their mode of action; Viral vaccines; Introduction to use of viral vectors in cloning and expression, and gene therapy.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Study of the structure of important animal viruses (rhabdo, influenza, paramyxo, hepatitis and retroviruses) using electron micrographs.
2. Study of the structure of important plant viruses (caulimo, gemini, tobacco ringspot, cucumber mosaic and alpha-alpha mosaic viruses) using electron micrographs.
3. Study of the structure of important bacterial viruses (ϕX174,T4,Ʒ) using electron micrograph.
4. Isolation and enumeration of bacteriophages (PFU) from water/sewage sample using double agar layer technique.
5. Studying isolation and propagation of animal viruses by chick embryo technique.
6. Study of cytopathic effects of viruses using photographs.
7. Perform local lesion technique for assaying plant viruses.

Reference Books

1. Pelczar M., Chan E.C.S. and Krieg, N.R. Microbiology. Tata Mc Grew Hill Publishing Co. Ltd., New Delhi.
2. Stainier R.V., Ingraham, J.L., Wheelis, M.L. and Painter P.R. The Microbial World. Printice-Hall of India (Pvt.) Ltd., New Delhi
3. Ellen Strauss, James Strauss.Viruses and Human Disease 2nd Edition. Academic Press
4. Christopher Burrell Colin Howard Frederick Murphy. Fenner and White's Medical Virology 5th Edition.Academic Press

5. Bernard N. Fields.Fields Virology Lippincott Williams & Wilkins
6. S. Jane Flint..Principles of Virology.American Society for Microbiology

CC6: Mycology & Phycology

Course learning outcomes: By the completion of this course the students able to-

Outcome 1. Describe useful and harmful activities of fungi and algae.

Outcome 2. Identify commonly available fungi and algae and their characteristics.

Outcome 3. Discuss how fungi and algae are used as biofertilizers in agriculture and as biopesticides.

Outcome 4. Grow mushroom in the laboratory.

THEORY COURSE
(4 Credits)

Unit – 1	**Mycology**: Characteristics, classification and cellular & thallus organization of fungi. General features, structure, nutrition, reproduction of different fungi group - Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes. Heterothallism and Para-sexuality. Sex hormones in fungi, physiological specialization, phylogeny of fungi.	**12 Lectures**
Unit – 2	General features, taxonomic status and evolutionary significance economic importance of important fungal genera - Mucor, Saccharomyces, Neurospora, Agaricus, Fusarium, Alternaria, Curvularia and Cladosporium. General account and importance of lichen. Important plant diseases caused by fungi- symptoms, disease cycles and control (Late & Early blight, Black rust, Smut, Wilt and Red rot).	**12 Lectures**
Unit – 3	Role of fungi in biotechnology, Application of fungi in food industry (Flavour & texture, Fermentation, Baking, Organic acids, Enzymes, Myco -proteins);	**12**

	Secondary metabolites (Pharmaceutical preparations); Agriculture (Biofertilizers); Mycotoxins; Biological control (Mycofungicides, Mycoherbicides, Mycoinsecticides). Mushroom and its cultivation.	**Lectures**
Unit – 4	General characteristics and evolution of algae. Occurrence, thallus organization, algae cell ultra-structure, pigments, flagella, eye- spot food reserves and vegetative, asexual and sexual reproduction. Classification of algae.	**12 Lectures**
Unit – 5	General features, structure and reproduction and economic importance of *Chlamydomonas, Chlorella*, Diatoms, *Microcystis*, *Oscillatoria*, *Spirulina*, *Anabaena*, *Nostoc*, *Rivularia* and *Scytonema*. Mass cultivation of algae as a source of protein.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Preparation of Potato Dextrose Medium.
2. Isolation and identification of pathogenic and non-pathogenic fungi.
3. Study of host-pathogen interaction.
4. Study of the vegetative and reproductive structures of following genera through temporary and permanent slides: *Mucor, Saccharomyces, Penicillium, Agaricus* and *Alternaria*
5. Purification and preservation of pure cultures of common algae and fungi.

Reference Books

1. Alexopoulus, C.J., Mims,C.W. and Blackwel, M, Introductory Mycology. John Wiley, New York.
2. Mehrotra, R.S. and K.R.Aneja An Introduction to Mycology. New Age International

Press, New Delhi.

3. Webster, J. Introduction to fungi. Cambridge University Press. Cambridge, U.K. (1985).
4. Bessey E.A. Morphology and Taxonomy of fungi. Vikas Publishing House Pvt. Ltd., New Delhi.
5. Jhon Webster and R W S Weber. Introduction to Fungi. Cambridge University Press 2007.
6. A. V. S. S. .Sambamurty. A Textbook of Algae. I.K. International Publishing House Pvt. Limited, 2010
7. H.D. Kumar and H.N. Singh.A Textbook on Algae (Macmillan international college edition)

CC7: Cell and Molecular Biology		
THEORY COURSE (4 Credits)		
Unit – 1	Concepts of cell- Prokaryotic & Eukaryotic cells. Cell organization of Prokaryotic cells with special reference to Bacteria. Eukaryotic cells - cell wall & plasma membrane; structure & function of cell organelles and inclusions. Episome, Mesosome, Flagella and Fimbrae.	**12 Lectures**
Unit – 2	Experimentalevidencesfornucleicacidasgeneticmaterial.Structureof DNA; ModelsofDNA replication. Enzymes, proteins and other factors involved in DNA replication. Mechanism of DNA replicationinprokaryotes&eukaryotes.SuperhelicityinDNA,linkingnumber,topological properties, mechanism of action of topoisomerases. Plasmids: Concept, Properties, types and application.	**12 Lectures**
Unit – 3	Cell cycle: Eukaryotic Cell Cycle, Regulation of Cell cycle progression, Events of Mitotic Phase, Meiosis and Fertilization. Cell cycle and Programmed cell death- Control system, intracellular control of cell cycle events, Apoptosis, extracellular control of cell growth and apoptosis. Growth phase in Bacteria.	**12 Lectures**
Unit – 4	Transcription: Definition, difference from replication, promoter - concept and strength of promoter RNA Polymerase and the transcription unit. Transcription in Eukaryotes: RNA polymerases, general Transcription factors. Translational machinery, Charging of tRNA, aminoacyl tRNA synthetases, Mechanisms of initiation, elongation and termination of polypeptides in both prokaryotes and eukaryotes, Fidelity of translation, Inhibitors of protein synthesis in prokaryotes and eukaryote	**12 Lectures**
Unit – 5	Split genes, concept of introns and exons, RNA splicing, spliceosome machinery, concept of alternative splicing, Polyadenylation and capping, Processing of rRNA, RNA interference: si RNA, miRNA and its significance. Principles of transcriptional regulation, regulation at initiation with examples	**12**

	from *lac* and *trp* operons, Sporulation in *Bacillus,* Yeast mating type switching , Changes in Chromatin Structure - DNA methylation and Histone Acetylation mechanisms.	**Lecture s**

LAB. COURSE

(2 Credits)

1. Study a representative plant and animal cell by microscopy.
2. Study of the structure of cell organelles through electron micrographs.
3. Cytochemical staining of DNA–Feulgen
4. Demonstration of the presence of mitochondria in striated muscle cells/cheek epithelial cell using vital stain Janus Green B
5. Study of polyploidy in Onion root tip by colchicine treatment.
6. Identification and study of cancer cells by photomicrographs.
7. Study of different stages of Mitosis.
8. Study of different stages of Meiosis.
9. Isolation of genomic and plasmid DNA from *E.coli*
10. Estimations of DNA and RNA using diphenylamine and orcinol reagent, and UV spectrophotometer (A260measurement)
11. Resolution and visualization of DNA by Agarose Gel Electrophoresis.

Reference Books

1. BenjaminLewin, GeneVII, OxfordUniversityPress, (2000).
2. BruceAlberts,AlexanderJohnson,JulianLewis,MartinRaff,KeithRoberts,PeterWalter, Molecular biologyoftheCell, 4th Edition. Garland publishing Inc. (2002).
3. Darnell,LodishandBaltimore, MolecularCellBiology, ScientificAmericanPublishingInc. (2000).
4. Watson.J.D,Baker.T.A,Bell.S.P,Gann.A.Levine.M.Losick.R, Molecular BiologyofGene, 5th Edition.TheBenjamin/CummingsPub.Co.Inc. (2003).
5. BrownT.A., GeneCloningand DNA analysis. 2nd Edition,ASMpress. (2004).
6. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
7. GlickBR andPasternakJJ, MolecularBiotechnology, 2nd Ed.ASM press. (2003).
8. Uldis N.Streips,RonaldE.Yasbin.Modern Microbial Genetics.2nd EditionWiley-

Liss,Inc.(2002).

9. Gardner E J, Simmons M J and Snupstad DP, Principles of genetics, 8th edition John Wiley & Sons, (2006).
10. Harvey Lodish; Arnold Berk; Chris A. Kaiser; Monty Krieger; Anthony Bretscher; Hidde Ploegh; Angelika Amon; Kelsey C. Martin, Stephen C. Harrison.Molecular Cell biology
11. David Baltimore and Harve Lodish. Molecular and Cell Biology. Macmilan learning. 2016

CC8: Microbial Genetics

Course learning outcomes: By the conclusion of this course, the students have -

Outcome 1. Understood genome organization of model organisms namely *E.coli* and *Saccharomyces,* and the molecular mechanisms that underlie mutations.

Outcome 2. Developed a fairly good knowledge about the three well known mechanisms by which genetic material is transferred among the microorganisms namely transformation, transduction and conjugation.

Outcome 3.Are able to describe different types of the extrachromosomal elements or the plasmids; the nature of the transposable elements in the prokaryotic and the eukaryotic cells.

Outcome 4. Hands on skills of isolation of plasmid DNA from bacterial cells and its visualization by performing agarose gel electrophoresis.

THEORY COURSE
(4 Credits)

Unit – 1	Genome organization: *E. coli, Saccharomyces, Tetrahymena*. Mutations and mutagenesis: Definition and types of Mutations; Physical and chemical mutagens; Molecular basis of mutations; Functional mutants (loss and gain of function mutants); Uses of mutations. Reversion and suppression: True revertants; Intra- and inter-genic suppression; Ames test; Mutator genes.	**12 Lectures**
Unit – 2	Microbial Genetics: Transformation- discovery, Griffith's experiment, mechanism of transformation; Factors affecting transformation process, Competence and development of competence in *S. Pneumonia.* **Transduction** – discovery, Lederberg and Tatum's experiment, mechanism and types of transduction- Generalized transduction,	**12 Lectures**

	Specialized transduction, Sexduction and abortive transduction.	
Unit – 3	Conjugation- discovery, experimental evidence, F-factor, F^+&Hfr, mechanism of conjugation, Cross between Hfr, F^+&F^- Conjugant and its application. Features of T4 genetics , Genetic basis of lytic *versus* lysogenic switch of phage lambda	**12 Lectures**
Unit – 4	Types of plasmids – F plasmid, R Plasmids, colicinogenic plasmids, Ti plasmids, linear plasmids, yeast- 2 ȝ plasmid, Plasmid replication and partitioning, Host range, plasmid- incompatibility, plasmid amplification, Regulation of copy number, curing of plasmids	**12 Lectures**
Unit – 5	Prokaryotic transposable elements – Insertion Sequences, composite and non-composite transposons, Replicative and Non replicative transposition, Mu transposon. Eukaryotic transposable elements - Yeast (Ty retrotransposon), Drosophila (P elements), Maize (Ac/Ds). Uses of transposons and transposition	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Preparation of Master and Replica Plates.
2. Study the effect of chemical (HNO2) and physical (UV) mutagens on bacterial cells.
3. Study survival curve of bacteria after exposure to ultraviolet (UV) light.
4. Isolation of Plasmid DNA from *E.coli.*
5. Study different conformations of plasmid DNA through agarose gel electrophoresis.
6. Demonstration of bacterial conjugation
7. Demonstration of bacterial transformation and transduction.
8. Demonstration of Ames test.

Reference Books

1. BenjaminLewin, GeneVII, OxfordUniversityPress, (2000).
2. BruceAlberts,AlexanderJohnson,JulianLewis,MartinRaff,KeithRoberts,PeterWalter, Molecular biologyoftheCell, 4th Edition. Garland publishing Inc. (2002).
3. Darnell,LodishandBaltimore, MolecularCellBiology, ScientificAmericanPublishingInc. (2000).
4. Watson.J.D,Baker.T.A,Bell.S.P,Gann.A.Levine.M.Losick.R, Molecular BiologyofGene, 5th Edition.TheBenjamin/CummingsPub.Co.Inc. (2003).
5. BrownT.A., GeneCloningand DNA analysis. 2nd Edition,ASMpress. (2004).
6. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
7. GlickBR andPasternakJJ, MolecularBiotechnology, 2nd Ed.ASM press. (2003).
8. Uldis N.Streips,RonaldE.Yasbin.Modern Microbial Genetics.2nd EditionWiley-Liss,Inc.(2002).
9. Gardner E J, Simmons M J and Snupstad DP, Principles of genetics, 8th edition John Wiley & Sons, (2006).
10. Harvey Lodish; Arnold Berk; Chris A. Kaiser; Monty Krieger; Anthony Bretscher;

Hidde Ploegh; Angelika Amon; Kelsey C. Martin, Stephen C. Harrison..Molecular Cell biology. Macmillan Higher Education

11. David Freifelder.Essentials of molecular biology.Jones and Bartlett Publishers, 1998

CC9: Microbial Physiology and Metabolism

Course learning outcomes: By the conclusion of this course, the students are capable of -

Outcome 1. Describing the growth characteristics of the microorganisms capable of growing under unusual environmental condition of temperature, oxygen, and solute and water activity.

Outcome 2. Describing the growth characteristics of the microorganisms which require different nutrient for growth and the associated mechanisms of energy generation for their survival like autotrophs, heterotrophs, chemolithoautotrophs etc.

Outcome 3.Differentiating concepts of aerobic and anaerobic respiration and how these are manifested in the form of different metabolic pathways in microorganisms.

THEORY COURSE (4 Credits)		
Unit – 1	Definitions of growth, measurement of microbial growth, Batch culture, Continuous culture, generation time and specific growth rate, synchronous growth, diauxic growth curve. Microbial growth in response to environment -Temperature (psychrophiles, mesophiles, thermophiles, extremophiles, thermodurics, psychrotrophs), pH (acidophiles, alkaliphiles), solute and water activity (halophiles, xerophiles, osmophilic), Oxygen (aerobic, anaerobic, microaerophilic, facultative aerobe, facultativeanaerobe),barophilic.	**12 Lectures**
Unit – 2	Microbial growth in response to nutrition and energy – Autotroph/Phototroph, heterotrophy, Chemolithoautotroph, Chemolithoheterotroph, Chemoheterotroph, Chemolithotroph, photolithoautotroph, Photoorganoheterotroph. Passive and facilitated diffusion. Primary and secondary active transport, concept of uniport, symport and antiport Group translocation Iron uptake	**12 Lectures**

Unit – 3	Concept of aerobic respiration, anaerobic respiration and fermentation Sugar degradationpathways i.e. EMP, ED, Pentose phosphate pathway TCA cycle. Electron transport chain: components of respiratory chain, comparison of mitochondrial and bacterial ETC, electron transport phosphorylation, uncouplers and inhibitors. Fermentation - Alcohol fermentation and Pasteur effect; Lactate fermentation (homofermentative and heterofermentative pathways), conceptof linear and branched fermentation pathways	**12 Lectures**
Unit – 4	Introduction to aerobic and anaerobic chemolithotrophy with an example each. Hydrogen oxidation (definition and reaction) and methanogenesis (definition and reaction). Introduction to phototrophic metabolism - groups of phototrophic microorganisms, anoxygenic vs. oxygenic photosynthesis with reference to photosynthesis in green bacteria, purple bacteria and Cyanobacteria	**12 Lectures**
Unit – 5	Anaerobic respiration with special reference to dissimilatory nitrate reduction(Denitrification; nitrate/nitrite and nitrate/ammonia respiration; fermentative nitrate reduction). Introduction to biological nitrogen fixation Ammonia assimilation. Assimilatory nitrate reduction, dissimilatory nitrate reduction, denitrification.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Study and plot the growth curve of *E.coli* by turbidometric and standard plate count methods.
2. Calculations of generation time and specific growth rate of bacteria from the graph plotted with the given data.
3. Effect of temperature on growth of *E.coli.*
4. Effect of pH on growth of *E.coli.*
5. Effect of carbon and nitrogen sources on growth of *E.coli.*
6. Effect of salt on growth of *E.coli.*
7. Demonstration of alcoholic fermentation.
8. Demonstration of the thermal death time and decimal reduction time of *E.coli.*

Reference Books

1. Stanier, Ingraham, Wheelis and Painter. The Microbial world. Mc Millan Educational Ltd., London.
2. Moat and Foster, Microbial Physiology. Wiley.
3. Umbreit. Essentials of Bacterial Physiology.
4. Skokatch. Bacterial Physiology and Metabolism.
5. Kushner, D.J. Microbial life in Extreme Environments. Academic Press.
6. Pawar. C.B. Cell Biology.
7. Sturart. Harris and Harris. The control of Antibiotic Resistance in Bacteria.
8. Franklin and Snow, Biochemistry of Antimicrobial Action. Chapman and Hall, New York.
9. Philipp. G. Mannual of Methods for General Bacteriology.
10. David T. Plummer. An Introduction to Practical Biochemistry.
11. Subba Rao, N.S. Soil Microorganisms and Plant Growth.

12. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
13. Willey,Sherwood,Woolverton. Prescott,Harley, and Klein's Microbiology McGraw-Hill publication
14. Tortora,Funke,Case. Microbiology.Pearson Benjamin Cummings.
15. JACQUELYN G. BLACK. Microbiology Principles and explorations. JOHN WILEY & SONS, INC.
16. Madigan,Martinko, Bender,Buckley,Stahl.Brock Biology of Microorganisms. Pearson
17. Tom Besty,D.C Jim Koegh.Microbiology Demystified McGRAW-HILL.
18. J. R. Sokatch Bacterial Physiology and Metabolism.Academic Press
19. Daniel R. Caldwell .Microbial Physiology and Metabolism .Star Pub Co; (1999)

CC10: Environmental Microbiology and Microbial Ecology

Course learning outcomes: By the completion of this course, the students -

Outcome 1. Have developed a fairly good knowledge and understanding of different types of environments and habitats where microorganisms grow including the microbiomes of the human gut and animal gut.

Outcome 2. Are able to identify the important role microorganisms play in maintaining healthy environment by degradation of solid/liquid wastes; how these activities of microorganisms are used in sewage treatment plants, production of activated sludge and functioning of septic tanks

Outcome 3.Have understood the significance of BOD/COD and various tests involving use of enumerating fecal *E.coli* for assessing quality of water.

Outcome 4. Have developed the practical skills for conducting experiments to assess the BOD/COD of wastewaters and their interpretation; practically assess the portability of drinking water by the use of standard microbiological tests.

THEORY COURSE

(4 Credits)

Unit – 1	TerrestrialEnvironment:Soilprofileandsoilmicroflora.AquaticEnvironment:Microfloraof fresh water and marine habitats Atmosphere: Aeromicroflora and dispersal of microbes. Animal Environment: Microbes in/on human body (microbiomics) & animal (ruminants) body. Extreme Habitats:Extremophiles:Microbesthrivingathigh&lowtemperatures,pH,highhydrostatic& osmotic pressures, salinity, & low nutrient levels.	**12 Lectures**
Unit –	Solid Waste management: Sources and types of solid waste, Methods of solid waste disposal	**12**

2	(composting and sanitary landfill). Liquid waste management: Composition and strength of sewage (BOD and COD), Primary, secondary (oxidation ponds, trickling filter, activated sludge process and septic tank) and tertiary sewage treatment	**Lectures**
Unit – 3	Principles and degradation of common pesticides, organic (hydrocarbons, oil spills) and inroganic (metals) matter, biosurfactants. Treatment and safety of drinking (potable) water, methods to detect potability of water samples: (a) standard qualitative procedure: presumptive test/MPN test, confirmed and completed tests for faecal coliforms (b) Membrane filter technique and (c) Presence/absence tests.	**12 Lectures**
Unit – 4	History, significance and developments in the field of microbial ecology. Contributions of Beijerinck, Winogradsky, Kluyver, Van Niel, Martin Alexander, Selman A. Waksman Structure and function of ecosystems. Microbial succession in decomposition of plant organicmatter. Biological Interaction: A. Microbe–Microbe Interactions- Mutualism, Synergis, Commensalism, Competition, Amensalism, Parasitism, Predation, Biocontrol agents. B. Microbe–Plant Interactions Roots, Aerial Plant surfaces, Biological Nitrogen fixation (symbiotic/nonsymbiotic - biofertilizers) C. Microbe-Animal Interactions - Role of Microbes in Ruminants, Nematophagus fungi, Luminescent bacteria as symbiont	**12 Lectures**
Unit – 5	Carbon cycle: Microbial degradation of cellulose, hemicelluloses, lignin and chitin Nitrogen cycle: Nitrogen fixation, ammonification, nitrification, denitrification and nitrate reduction Phosphorus cycle: Phosphate immobilization and solubilisation. Sulphur cycle: Microbes involved in sulphur cycle Other elemental cycles: Iron and manganese	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Analysis of soil pH, moisture content, water holding capacity, percolation, capillary action.
2. Isolation of microbes (bacteria & fungi) from soil (28ºC&45ºC).
3. Isolation of microbes (bacteria & fungi) from rhizosphere and rhizoplane.
4. Assessment of microbiological quality of water.
5. Determination of BOD of wastewater sample.
6. Study the presence of microbial activity by detecting (qualitatively) enzymes (dehydrogenase, amylase, urease) in soil.
7. Isolation of *Rhizobium* from root nodules.

Reference Books

1. Medigan, M.T., Martinko, J. M. and Parker, J. Brock Biology of Microorganisms. Pearson Education Inc. , New York
2. Alexander, M John. Microbial ecology. Wiley & Sons, Inc., New York.
3. Alexander, M John. Introduction to soil microbiology.Wiley & Sons Inc., New York.
4. Barker, KH, and Herson, D.S. Bioremediation. Mc Craw Hill Inc., New York.
5. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
6. Willey,Sherwood,Woolverton. Prescott,Harley, and Klein's Microbiology McGraw-Hill publication
7. Tortora,Funke,Case. Microbiology.Pearson Benjamin Cummings.
8. JACQUELYN G. BLACK. Microbiology Principles and explorations. JOHN WILEY & SONS, INC.
9. Madigan,Martinko, Bender,Buckley,Stahl.Brock Biology of Microorganisms. Pearson
10. Tom Besty,D.C Jim Koegh.Microbiology Demystified McGRAW-HILL.

CC11: Industrial Microbiology

Course learning outcomes: By the conclusion of this course, the students -

Outcome 1. Are capable of describing a large number of substrate that are used for the industrial fermentation processes.

Outcome 2.Have developed an understanding of different types of reactors or fermenters which are used for laboratory, pilot and industrial scale fermentations and their processes parameters.

Outcome 3.Have acquired a detailed knowledge of number of products which are produced by industrial fermentation processes

THEORY COURSE

(4 Credits)

Unit – 1	Brief history and developments in industrial microbiology. Sources of industrially important microbes and methods for their isolation, preservation and maintenance of industrial strains, strain improvement, Crude and synthetic media; molasses, corn- steep liquor, sulphite waste liquor, whey, yeast extract and protein hydrolysates	**12 Lectures**
Unit – 2	Types of fermentation processes - Solid-state and liquid-state (stationary and submerged) fermentations; batch, fed-batch (e.g. baker's yeast) and continuous fermentations. Components of a typical bio-reactor, Types of bioreactors-Laboratory, pilot- scale and production fermenters, constantly stirred tank and air-lift fermenters, Measurement and control of fermentation parameters - pH, temperature, dissolved oxygen, foaming and aeration	**12 Lectures**
Unit – 3	Down-stream processing; Cell disruption, filtration, centrifugation, solvent extraction, precipitation, lyophilization and spray drying.	

	Microbial cells as food. SCP -mushroom cultivation,	**12 Lectures**
Unit – 4	Microbial production of industrial products (micro-organisms involved, media, fermentation conditions, downstream processing and uses)- Citric acid, ethanol, penicillin, glutamic acid, Vitamin B12. Enzymes (amylase, protease, lipase) wine, beer.	**12 Lectures**
Unit – 5	Methods of immobilization, advantages and applications of immobilization, large scale applications of immobilized enzymes (glucose isomerase and penicillin acylase). Role of Microbes in Medicine and textile industry.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Study different parts of fermenter
2. Microbial fermentations for the production and estimation (qualitative and quantitative) of:

3. Enzymes: Amylase and Protease
4. Amino acid: Glutamic acid
5. Organic acid: Citric acid
6. Alcohol: Ethanol
7. A visit to any educational institute/industry to see an industrial fermenter, and other downstream processing operations.

Reference Books

1. Richard H. Baltz. Julian E Davies and Arnold L.Demain Manual of Industrial Microbiology and Biotechnology. 3rd edition, ASM Press (2010).
2. Daniel Forciniti. Industrial Bioseperation: Principles and practice. 1st edition, Wiley-Blackwell (2008).
3. Reed. G. Prescott and Dunn's Industrial Microbiology. CBS Publishers. (1999).
4. Demain, A. L. Industrial Microbiology and Biotechnology. 2nd Edition. (2001).
5. EL Mansi. E.M.T. FermentationMicrobiologyand Biotechnology. 2ndEdition,CRC Taylor&Francis (2007).
6. Waites,M.J.,Morgan, N.L.,Rockey, J.S.andHigton,G.Industrial Microbiology: An lntroduction. Blackwell SciencePublishers(2002).
7. Casida LE, Industrial Microbiology, J. Wiley, (1968).
8. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
9. Willey,Sherwood,Woolverton. Prescott,Harley, and Klein's Microbiology McGraw-Hill publication
10. Tortora,Funke,Case. Microbiology.Pearson Benjamin Cummings.
11. JACQUELYN G. BLACK. Microbiology Principles and explorations. JOHN WILEY & SONS, INC.

12. Madigan,Martinko, Bender,Buckley,Stahl.Brock Biology of Microorganisms. Pearson
13. Tom Besty,D.C Jim Koegh.Microbiology Demystified McGRAW-HILL.
14. Wulf Crueger.Cruegers Biotechnology: A Textbook of Industrial Microbiology 2017

CC12: Medical and Veterinary Microbiology, and Immunology

Course learning outcomes: By the conclusion of this course, the students clearly -

Outcome 1. Understood the basic and general concepts of causation of disease by the pathogenic microorganisms and the various parameters of assessment of their severity including the broad categorization of the methods of diagnosis.

Outcome 2. Developed a thorough understanding of common bacterial, viral, fungal, parasitic diseases of human being including some very important diseases of the animals also.

Outcome 3. Conceptualized the protective role of the immune system of the host and developed an understanding of the basic components as well as the mechanisms underlying the immune system and its response to pathogenic microorganisms.

Outcome 4. Are able to conduct experiments for growing common bacteria in different microbiological media, antibiotic sensitivity determination and antigen antibody reaction (precipitation test in the agarose)

THEORY COURSE

(4 Credits)

Unit – 1	Normal microflora of the human body: Importance of normal microflora, normal microflora of skin, throat, gastrointestinal tract, urogenital tract. Host pathogen interaction: Definitions - Infection, Invasion, Pathogen, Pathogenicity, Virulence, Toxigenicity, Carriers and their types, Opportunistic infections, Nosocomial infections. Transmission of infection, Pathophysiologic effects of LPS. Collection, transport and culturing of clinical samples, principles of different diagnostic tests (ELISA, Immunofluorescence, Agglutination based tests, Complement fixation, PCR, DNA probes).	**10 Lectures**

Unit – 2	List of diseases of various organ systems and their causative agents. Symptoms, mode of transmission, prophylaxis and control of the diseases caused by Streptococcus pyogenes, *Mycobacterium,Haemophilus influenzae*, *tuberculosis*, *Bacillus anthracis*, *Clostridium tetani*, *Treponema pallidum*, *Clostridium difficile*, and the viruses causing Polio, Herpes, Hepatitis, Dengue, AIDS, influenza and Japanese encephalitis.	**10 Lectures**
Unit – 3	Study of following animal diseases with respect to etiology, symptoms, mode of transmission, prophylaxis and control: FMD, swine flu, bird flu, Rabies, bovine tuberculosis, Marek's, ranikhet, brucellosis, distemper.	**10 Lectures**
Unit – 4	Mycoses: Cutaneous mycoses: Tinea pedis (Athlete's foot) Systemic mycoses: Histoplasmosis Opportunistic mycoses: Candidiasis. Occurrence, habitat, morphology and reproduction of Protozoa. Structure and reproduction of important Protozoans- Entamoeba, Giardia, Trichomonas, Leishmania, Trypanosoma and Plasmodium.	**10 Lectures**
Unit – 5	**Immune system:** Structure and function of the cells, tissues and organs of immune system. Types of immunity - Humoral and cell-mediated, innate, acquired immunity. Complement system – function and pathways. Antigens and Antibodies: types, properties. Haptens, adjutants, Immunoglobulins: Structure types, Properties and their function - Theory of antibody production. Antigen-Antibody Interactions, Agglutination, Precipitation, Complement fixation test. Hypersensitivity reactions; IgE mediated Type I Hypersensitivity, Antibody-mediated cytotoxic (Type II) Hypersensitivity, Immune complex mediated (Type III) Hypersensitivity, DTH mediated (Type IV) Hypersensitivity.	**20 Lectures**

LAB. COURSE

(2 Credits)

Identify bacteria (any three of *E.coli*, *Salmonella*, *Pseudomonas*, *Staphylococcus*, *Bacillus*) using laboratory strains on the basis of cultural, morphological and biochemical characteristics: IMViC, TSI, nitrate reduction, urease production and catalase tests.

1. Study of composition and use of important differential media for identification of bacteria: EMB Agar, McConkey agar, Mannitol salt agar, Deoxycholate citrate agar, TCBS
2. Study of bacterial flora of skin by swab method.
3. Perform antibacterial sensitivity by Kirby-Bauer method.
4. Determination of minimal inhibitory concentration (MIC) of an antibiotic.
5. Study symptoms of the diseases with the help of photographs: Polio, anthrax, herpes, chickenpox, HPV warts, AIDS (candidiasis), dermatomycoses (ringworms).
6. Study of various stages of malarial parasite in RBC using permanent mounts.

Reference Books

1. Ananthanarayan R and Paniker CKJ. Textbook of Microbiology. 7th Edition. University Press Publication. (2005).
2. Brooks GF, Carroll KC, Butel JS and Morse SA. Jawetz, Melnick and Adelberg's Medical Microbiology. 24th edition. McGraw Hill Publication. (2007).
3. Goering R, Dockrell H, Zuckerman M and Wakelin D. Mims Medical microbiology. 4th edition. Elsevier. (2007).
4. Bernard, Davis B. Dulbecco, Eisen and Ginsberg. Microbiology including immunology and molecular Genetics. 3rd Edition
5. Roitt I. Essential Immunology. 10th Ed. Blackwell Science.
6. Kuby. Immunology. 4th edition. W. H. Freeman & company.
7. Ellen Strauss, James Strauss. Viruses and Human Disease 2nd Edition.Academic Press

8. Christopher Burrell Colin Howard Frederick Murphy.Fenner and White's Medical Virology 5th Edition.Academic Press
9. Patrick R. Murray PhD, Ken S. Rosenthal PhD,Michael A. Pfaller MD.Medical microbiology.Elsvier
10. Jawetz.Medical microbiology.Mc. Graw Hill
11. Kenneth, J. Ryan.Medical microbiology, Sherri’s an introduction to infectious diseases.Mc. Graw Hill

CC13: Agriculture, Food and Dairy Microbiology		
Outcome 1. Developed a clear understanding of the multifarious roles of microorganisms in soil, in association with plants and thus in the field of agriculture. **Outcome 2**.Are able to describe the role of microorganisms in the production of food, its spoilage, including their role in homemade fermented foods. **Outcome 3**.Are able to identify the role of microorganisms in the causation of the diseases and how to protect against food-borne pathogens. **Outcome 4.** Developed experimental skills for testing the milk and different foods for the presence of microorganisms		
THEORY COURSE **(4 Credits)**		
Unit – 1	History of Agricultural Microbiology; Microbes and their importance in maintenance of soil, Biogeochemical cycles, role of microbes in maintaining the fertility of soil. Bio fertilizers – Bacterial, -Azotobacter and vermiform compost. Soil microorganism -association with vascular plants- phyllosphere, Rhizobium, Rhizoplane associative nitrogen fixation. Biofertilizers- Cyanobacterial and Azolla.	**12 Lectures**
Unit – 2	Intrinsic and extrinsic factors that affect growth and survival of microbes in foods, natural flora and source of contamination of foods in general. Principles, Spoilage of vegetables, fruits, meat, eggs, milk and butter, bread, canned Foods. Principles of food preservation: temperature, canning, drying, irradiation, microwave processing and aseptic packaging, chemical methods of food preservation: salt, sugar, organic acids, SO2, citrates, benzoates,	**12 Lectures**

	nitrite and nitrates etc.	
Unit – 3	Dairy starter cultures, fermented dairy products: yogurt, acidophilus milk, kumiss, kefir, dahi and cheese, other fermented foods: dosa, sauerkraut, soy sauce and tampeh, Probiotics: Health benefits, types of microorganisms used, probiotic foods available in market. Utilization and disposal of dairy by-product – whey.	**12 Lectures**
Unit – 4	Food borne diseases (causative agents, foods involved, symptoms and preventive measures)- Food intoxications: Staphylococcus aureus, Clostridium botulinum and mycotoxins; Food infections: Bacillus cereus, Vibrio parahaemolyticus, Escherichia coli, Salmonellosis, Shigellosis, Yersinia enterocolitica, Listeria monocytogenes and Campylobacter jejuni	**12 Lectures**
Unit – 5	Food sanitation and control; HACCP, Indices of food sanitary quality and sanitizers. Cultural and rapid detection methods of food borne pathogens in foods and introduction to predictive microbiology. Genetically modified foods, Nutraceuticals, Biosensors in food, Applications of microbial enzymes in dairy industry [Protease, Lipases].	**12 Lectures**

LAB. COURSE

(2 Credits)

1. MBRT of milk samples and their standard plate count.
2. Alkaline phosphatase test to check the efficiency of pasteurization of milk.
3. Isolation of any foodborne bacteria from food products.Isolation of spoilage microorganisms from spoiled vegetables/fruits.
4. Isolation of spoilage microorganisms from bread.
5. Preparation of Yogurt/Dahi.

Reference books

1. Stanbury, PF., Principles of Fermentation Technology. Whittaker, A and Hall, S.J 2nd Edition. Pergamon Press (1995).
2. Banwart, GJ. Basic Food Microbiology. CBS Publishers and Distributors, Delhi. (1989).
3. Hobbs BC and Roberts D. Food poisoning and Food Hygiene. Edward Arnold (A division of Hodder and Stoughton) London.
4. Joshi. Biotechnology: Food Fermentation Microbiology, Biochemistry and Technology. Volume 2.
5. John Garbult. Essentials of Food Microbiology. Arnold International.
6. John C. Ayres. J. Orwin Mundt. William E. Sandinee. Microbiology of Foods. W.H. Freeman and Co.
7. D. J. Bagyaraj and G. Rangaswami.AGRICULTURAL MICROBIOLOGY. Prentice Hall of India Pvt Ltd.2005
8. N S Subba Rao. Soil Microbiology. Oxford and IBH publishing Company 2009
9. Photis Papademas.Dairy Microbiology: A Practical Approach. CRC Press
10. Rao M.K..Food and Dairy Microbiology. Manglam Publishers
11. William Frazier. Food Microbiology. McGraw Hill Education

12.Jay, James M., Loessner, Martin J., Golden, David A. Modern Food Microbiology.Springer .

CC14: Advanced Microbiology		
Course learning outcomes: By the conclusion of this course, the students - **Outcome 1**. Can explain salient characteristics of genomes of representative microorganisms. **Outcome 2**. Have understood the concept and importance of metagenomics. **Outcome 3.**Have developed an initial understanding of recent developments of host-microbe interactions, synthetic biology, viable but non-culturable forms of microorganism etc. **Outcome 4.** Are able to extract DNA from bacteria / soil and perform PCR for 16s Ribosomal genes using universal primers and interpret the results.		
THEORY COURSE **(4 Credits)**		
Unit – 1	Evolution of Microbial Genomes**:** Salient features of sequenced microbial genomes, core genomepool,flexiblegenomepoolandconceptofpangenome,Horizontalgenetransfer(HGT), Evolution of bacterial virulence - Genomic islands, Pathogenicity islands (PAI) and their characteristics	**12 Lectures**
Unit – 2	Metagenomics**:** Brief history and development of metagenomics, Understanding bacterial diversity using metagenomics approach, Prospecting genes of biotechnological importance using Metagenomics Basic knowledge of viral metagenome, meta transcriptomics, metaproteomics and metabolomics.	**12 Lectures**

Unit – 3	Molecular Basis of Host-Microbe Interaction:Epiphytic fitness and its mechanism in plant pathogens, Hypersensitive response (HR) to plant pathogens and its mechanism, Type three secretion systems (TTSS) of plant and animal pathogens, Biofilms: types of microorganisms, molecular aspects and significance in environment, health care, virulence and antimicrobial resistance	**12 Lectures**
Unit – 4	Systems and Synthetic Biology: Networking in biological systems, Quorum sensing in bacteria,Co-ordinatedregulationofbacterialvirulencefactors,Basicsofsynthesisofpoliovirus in laboratory, Future implications of synthetic biology with respect to bacteria and viruses	**12 Lectures**
Unit – 5	Microbiomes and importance of microbial communities, VBNC (viable but not culturable bacteria). Genetically modified organisms and their uses. Modern methods of rapid identification of microbes (PCR, mass spectrometry, fluorescence based techniques). CRISPR-Cas system.	**12 Lectures**
	LAB. COURSE (2 Credits)	
	1. Extraction of metagenomics DNA from soil. 2. Understand the impediments in extracting metagenomics DNA from soil. 3. PCR amplification of metagenomics DNA using universal 16s ribosomal gene primers. 4. Case study to understand how the polio virus genome was synthesized in the laboratory. 5. Case study to understand how networking of metabolic pathways in	

bacteria takes place.

Reference Books

1. BenjaminLewin, GeneVII, OxfordUniversityPress, (2000).
2. BruceAlberts,AlexanderJohnson,JulianLewis,MartinRaff,KeithRoberts,PeterWalter, Molecular biologyoftheCell, 4th Edition. Garland publishing Inc, (2002).
3. Darnell,LodishandBaltimore, MolecularCellBiology, ScientificAmericanPublishingInc. (2000).
4. Watson.J.D,Baker.T.A,Bell.S.P,Gann.A.Levine.M.Losick.R, Molecular BiologyofGene, 5th Edition.TheBenjamin/CummingsPub.Co.Inc (2003).
5. DavidFrifielder,Stanely R.Maloy, Molecularbiologyand Microbialgenetics. 2nd Edition,JonesandBarlettPublishers. (1994).
6. BrownT.A., GeneCloningand DNA analysis. 2nd Edition,ASMpress. (2004).
7. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
8. GlickBR andPasternakJJ, MolecularBiotechnology, 2nd Ed.ASM press. (2003).
9. Uldis N.Streips,RonaldE.Yasbin.Modern Microbial Genetics.2nd EditionWiley-Liss,Inc. (2002).
10. Russel P J, Essential genetics, Blackwell Science Inc, 2 sub edition, (1987).

Gardner E J, Simmons M J and Snupstad

DISCIPLINE SPECIFIC ELECTIVE (DSE) COURSES

DSE1: Biophysics, Biomathematics & Biostatistics

Course learning outcomes: By the conclusion of this course, the students clearly -

Outcome 1. Understand the basic physical parameters of cells or biological processes and basic methods used to study these.

Outcome 2.Have developed basic knowledge of mathematics as applied to biological phenomenon.

Outcome 3. Have developed basic concepts of statistics and their importance

THEORY COURSE
(4 Credits)

Unit – 1	Diffusion and Brownian motion; Langevin eqn., diffusion eqn., Einstein Relation. Biological applications - Sedimentation, bacterial metabolism, pattern formation. Electrostatic interactions - Poisson-Boltzmann eqn and its solution. Cooperative transitions - Helix coil transition, Stretching of macromolecules, Protein folding, Unzipping of DNA Machines in membranes - Electro-osmotic effects, Ion pumping. Nerve Impulses - Action Potentials, Ion Channels; Physical Techniques and related biology - X-ray diffraction, light and neutron scattering, Nuclear magnetic Resonance, Fluorescence, Tomography, Patch clamps	**12 Lectures**
Unit – 2	Sets. Functions and their graphs: polynomial, linear, power,periodic, exponential and logarithmic functions. Illustration of these functions in biological systems; Basic idea of differentiation and integration.	**12 Lectures**
Unit – 3	Statistical methods: Applications and scope of statistics, Principles of statistical analysis of biological data. Sampling parameters. Difference between sample and population, Sampling errors, Censoring, difference	**12 Lectures**

	between parametric and non-parametric statistics; Mean and Variance of discrete and continuous distributions namely binomial, poisson and normal distribution. Fitting of distributions.	
Unit – 4	Measures of central tendency, Mean, Median and Mode; Measures of dispersion, standard deviation and variance; Skewness, kurtosis; Probability; Discrete and continuous random variable, Curve fitting; Correlation and regression. Emphasis on examples from biological systems;	**12 Lectures**
Unit – 5	Sampling size determination, Testing of hypothesis, Level of significance and degree of freedom; Large sample test based on normal distribution; Small sample test based on *t*-test, Z-testandFtest;Confidenceinterval;Distribution-freetest;Chi-squaretest; Basic introduction to multivariate statistics.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Word Problems based on Differential Equations
2. Mean, Median, Mode from grouped and ungrouped Dataset
3. Standard Deviation and Coefficient of Variation
4. Skewness and Kurtosis
5. Curve fitting
6. Correlation
7. Regression
8. Finding area under the curve using normal probability
9. Testing of Hypothesis-Normal Distribution ,t-test and Chi-Square-test
10. Confidence Interval

Reference Books

1. Wilson& Walker.Principles andTechniquesinPractical Biochemistry. 5th Edition Cambridge University Press (2000).
2. Khan I A and Khan I A. Fundamentals of Biostatistics, Ukaaz Publications,

(1994).MurphyD.B. FundamentalofLightMicroscopy&Electron Imaging.1st Edition.Wiley-Liss.(2001).

4. Beckner, W.M., Kleinsmith L.J and Hardin J. The world of cell. IV edition Benjamin/Cummings (2000).
5. Myra L. Samuels, Jeffrey A.Witmer, Andrew A. Schaffner. Statistics for the life sciences.Pearson
6. Chap T. Le.IntroductoryBiostatistics.Wiley- Interscience
7. Jagdish Arya and Robin W. Lardner. Mathematics for the Biological Sciences.Prentice Hall New Jersey
8. Chap T. Le and Lynn E. Eberly .Introductory Biostatistics 2nd Edition . Wiley (2016)

DSE2: Basic Computer & Bioinformatics

Course learning outcomes: By the conclusion of this course, the students have -

Outcome 1. Developed skills to use computers for analysis of biological data.

Outcome 2. Skill to use important biological databases, use tools to retrieve data, and compare the data of the biological macromolecules

Outcome 3. Developed basic skills for data retrieval, representation, analysis and interpretation

THEORY COURSE
(4 Credits)

Unit – 1	**Computer fundamentals:** Basic concept of computer organization, generations of computer, hardware, software, number system, flow chart and basics of operating systems (windows, unix), Classification of computers and computer languages. **Internet & Web:** MS office and internet - introduction, importance, requirements of internet. Electronic mailing, chatting, search engines, webpages.	**12 Lectures**
Unit – 2	RDBMS - Definition of relational database; Mode of data transfer (FTP, SFTP, SCP), advantage of encrypted data transfer. Biological databases - nucleic acid, genome, protein sequence and structure, gene expression databases, Database of metabolic pathways, Mode of data storage - File formats - FASTA, Genbank and Uniprot, Data submission & retrieval from NCBI, EMBL, DDBJ, Uniprot, PD.	**12 Lectures**
Unit – 3	Local and global sequence alignment, pairwise and multiple sequence alignment. Scoring an alignment,scoringmatrices,PAM&BLOSUMseriesofmatrices.Typesofphylogenetictrees, Different approaches of phylogenetic tree construction - UPGMA, Neighbour	**12 Lectures**

	joining, Maximum Parsimony, Maximum likelihood	
Unit – 4	Diversity of Genomes: Viral, prokaryotic & eukaryotic genomes; Genome, transcriptome, proteome; 2-D gel electrophoresis, MALDI TOF spectroscopy; Major features of completed genomes of *E.coli*, *S.cerevisiae*, and *Arabidopsi*s.	**12 Lectures**
Unit – 5	Hierarchy of protein structures, modeling structural classes; Motifs, Folds and Domains. Protein structure prediction in presence and absence of structure template Energy minimizations and evaluation by Ramachandran plot. Protein structure and rational drug design	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Introduction to different operating systems - UNIX, LINUX and Windows
2. Introduction to bioinformatics databases (any three): NCBI/PDB/DDBJ, Uniprot, PDB
3. Sequence retrieval using BLAST
4. Sequence alignment & phylogenetic analysis using clustal W& phylip
5. Picking out a given gene from genomes using Genscan or other softwares (promoter region identification, repeat in genome, ORF prediction). Gene finding tools (Glimmer, GENSCAN), Primer designing, Genscan/Genetool
6. Protein structure prediction: primary structure analysis, secondary structure prediction using psi-pred, homology modeling using Swiss model. Molecular visualization using jmol, Protein structure model evaluation(PROCHECK)
7. Prediction of different features of a functional gene

Reference Books

1. Mount D., Bioinformatics: Sequence and Genome Analysis. Cold Spring Harbor Laboratory Press, New York. (2004).
2. Baxevanis, A.D. and Francis Ouellellette, B.F., Bioinformatics- A Practical Guide to the Analysis of Genes and Proteins. Wiley India Pvt Ltd. (2009).

3. Teresa K. Attwood, David J. Parry-Smith, Introduction to Bioinformatics. Pearson Education. (1999).
4. Jean-michel Claverie Cedric Notredame. Bioinformatics for Dummies. Publisher: Dummies (2007).
5. Arthur M. Lesk.Introduction to bioinformatics. Oxford University Press.(2004)
6. Dan E. Krane and Michael L. RaymerFundamental Concepts of Bioinformatics (2002)
7. KRANE .Fundamental Concepts of Bioinformatics, (2003)
8. Teresa Attwood.Introduction to Bioinformatics . (2007)

DSE3: Microbial Biotechnology

Course learning outcomes: By the conclusion of this course, the students have -

Outcome 1. Developed an understanding how microbiology is relevant to technological developments for agriculture and environment.

Outcome 2.Developed an understanding how microbiology is relevant to technological developments for industries related to food and fermentations.

Outcome 3. Developed an understanding how developments in recombinant DNA technology is juxtaposed with microbially-based technological developments for agriculture, industry and environment.

THEORY COURSE

(4 Credits)

Unit – 1	Microbial biotechnology: Scope and its applications in human therapeutics, agriculture (Biofertilizers, PGPR, Mycorrhizae), environmental, and food technology. Use of prokaryotic and eukaryotic microorganisms in biotechnological applications Genetically engineered microbes for industrial applications: Bacteria and yeast	**12 Lectures**
Unit – 2	Recombinant microbial production processes in pharmaceutical industries - Streptokinase, recombinant vaccines (Hepatitis B vaccine). Microbial polysaccharides and polyesters, Microbial production of bio-pesticides, bioplastics Microbial biosensors	**12 Lectures**
Unit – 3	Microbial based transformation of steroids and sterols. Bio-catalytic processes and their industrial applications: Production of high fructose syrup and production of cocoa butter substitute	**12 Lectures**

Unit – 4	Microbial product purification: filtration, ion exchange & affinity chromatography techniques Immobilization methods and their application: Whole cell immobilization. RNAi and its applications in silencing genes, drug resistance, therapeutics, and host pathogen interactions	**12 Lectures**
Unit – 5	Bio-ethanol and bio-diesel production: commercial production from lignocellulosic waste and algal biomass, Biogas production: Methane and hydrogen production using microbial culture. Microorganisms in bioremediation: Degradation of xenobiotics, mineral recovery, removal of heavy metals from aqueous effluents	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Study yeast cell immobilization in calcium alginate gels
2. Study enzyme immobilization by sodium alginate method
3. Pigment production from fungi (*Trichoderma* / *Aspergillus* /*Penicillium*)
4. Isolation of xylanase or lipase producing bacteria

Reference Books

1. Richard H. Baltz. Julian E Davies and Arnold L.DemainManual of Industrial Microbiology and Biotechnology. 3rd edition, ASM Press (2010).
2. Daniel Forciniti. Industrial Bioseperation :Principles and practice. 1st edition edition, Wiley-Blackwell (2008).
3. Reed. G. Prescott and Dunn's Industrial Microbiology. CBS Publishers. (1999).
4. Demain, A. L. Industrial Microbiology and Biotechnology. 2nd Edition. (2001).
5. EL Mansi. E.M.T., FermentationMicrobiologyand Biotechnology. 2ndEdition,CRC Taylor&Francis (2007).
6. Waites,M.J.,Morgan, N.L.,Rockey, J.S.andHigton,G.Industrial Microbiology: An lntroduction. Blackwell SciencePublishers(2002).

7. Casida LE, Industrial Microbiology, J. Wiley, (1968).
8. James Bailey and David Ollis, Fundamentals of Biochemical Engineering, 2nd edition, McGraw-Hill, (1986).
9. Jayanta Kumar Patra Gitishree Das Han-Seung Shin. Microbial Biotechnology. Springer

DSE4: Hereditary and Evolution		
Course learning outcomes: By the conclusion of this course, the students have - **Outcome 1**. Developed perception of evolution taking examples from well-studied models organisms of bacteria, fungi and other organisms. **Outcome 2**. Good understanding of concepts of Mendelian genetics and structural organizations of chromosomes. **Outcome 3**. Developed practical skills to do karyotyping and pedigree analysis.		
THEORY COURSE **(4 Credits)**		
Unit – 1	**Introduction to Genetics:** Historical developments; Model organisms in genetic analyses and experimentation: *Escherichia coli*, *Saccharomyces cerevisiae, Neurospora crassa*, *Caenorhabditis elegans Drosophila melanogaster*, *Arabidopsis thaliana*. Mendel's Laws: Dominance, segregation, independent assortment, deviation from Mendelian inheritance, Chromosome theory of inheritance: Allele, multiple alleles, pseudoallele, complementation tests.	**12 Lectures**
Unit – 2	Extensions of Mendelian genetics: Allelic interactions, concept of dominance, recessiveness, Incomplete dominance and co-dominance, Multiple alleles, Epistasis, penetrance and expressivity. Linkage and recombination of genes, Cytological basis of crossing over, Crossing over at four- strand stage, Molecular mechanisms of crossing over, mapping	**12 Lectures**
Unit – 3	Interaction of genes (Factor hypothesis) – Complementary gene, Inhibitory gene, Duplicate gene And lethal gene.Rules of extranuclear inheritance,Organelleheredity-	**12 Lectures**

	Chloroplast mutations in *Chlamydomonas*,mitochondrial,mutations in *Saccharomyces*,Maternal effects–Shellcoilingin *Limnaeaperegra* Infectious heredity - Kappa particles in *Paramecium.*	
Unit – 4	Structural organization of chromosomes - centromeres, telomeres and repetitive DNA, Packaging DNA molecules into chromosomes, Concept of euchromatin and heterochromatin, Normal and abnormal karyotypes of human chromosomes, Chromosome banding, Giant chromosomes: Polytene and lampbrush chromosomes, Variations in chromosome structure: Deletion, duplication, inversion and translocation, Variation in chromosomal number and structural abnormalities- Klinefelter syndrome, Turner syndrome, Down syndrome	**12 Lectures**
Unit – 5	Homologous and non-homologous recombination, including transposition, site-specific recombination. Pedigree analysis, LOD score for linkage testing, karyotypes, genetic disorders. Polygenic inheritance, heritability and its measurements, QTL mapping	**12 Lectures**

LAB. COURSE
(2 Credits)

1. Mendelian deviations in dihybrid crosses
2. Studying Barr Body with the temporary mount of human cheek cells
3. Studying *Rhoeo* translocation with the help of photographs
4. Karyotyping
5. Chi-Square Analysis
6. Study of polytene chromosomes using temporary mounts of salivary glands of *Chiromonas/ Drosophila* larvae
7. Study of pedigree analysis

8. Analysis of a representative quantitative trait

Reference books

1. BenjaminLewin, GeneVII, OxfordUniversityPress, (2000).
2. DavidFrifielder,Stanely R.Maloy, Molecularbiologyand Microbialgenetics. 2nd Edition,JonesandBarlettPublishers. (1994).
3. BrownT.A., GeneCloningand DNA analysis. 2nd Edition,ASMpress. (2004).
4. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
5. GlickBR andPasternakJJ, MolecularBiotechnology, 2nd Ed.ASM press. (2003).
6. Uldis N.Streips,RonaldE.Yasbin.Modern Microbial Genetics.2nd EditionWiley-Liss,Inc.(2002).
7. L. C. Dunn.Heredity and Variation: Continuity and Change in the Living World. LLC 2012

DSE5: Biosafety and Intellectual Property Rights

Course learning outcomes: By the conclusion of this course, the students have -

Outcome 1. Full knowledge of working in a microbiology laboratory taking all safety measures, handing of live bacteria, disposal of infectious waste, care of the equipment requiring safety audit

Outcome 2. Developed knowledge of basic concepts related to IPR.

Outcome 3. Developed knowledge of patent filing, and some well-known/well-publicized case studies related to IPR

THEORY COURSE
(4 Credits)

Unit – 1	Biosafety: Introduction; biosafety issues in biotechnology; Biological Safety Cabinets &their types; Primary Containment for Biohazards; Biosafety Levels of Specific Microorganisms AERB/RSD/RES guidelines for using radioisotopes in laboratories and precautions.	**12 Lectures**
Unit – 2	Biosafety Guidelines: Biosafety guidelines and regulations(National and International); GMOs/LMOs- Concerns and Challenges; Role of Institutional Biosafety Committees (IBSC), RCGM, GEAC etc. for GMO applications in food and agriculture; Environmental release of GMOs; Risk Analysis; Risk Assessment; Risk management and communication; Overview of International Agreements - Cartagena Protocol.	**12 Lectures**
Unit – 3	IntroductiontoIntellectualProperty:Patents,Types,Trademarks,Copyright&RelatedRights, Industrial Design and Rights, Traditional Knowledge, Geographical	**12 Lectur**

	Indications- importance of IPR – patentable and non patentables – patenting life – legal protection of biotechnological inventions – World Intellectual Property Rights Organization (WIPO)	**es**
Unit – 4	Grant of Patent and Patenting Authorities: Types of patent applications: Ordinary, PCT, Conventional, Divisional and Patent of Addition; An introduction to Patent Filing Procedures; Patent licensing and agreement; Patent infringement- meaning, scope, litigation, case studies, Rights and Duties of patent owner.	**12 Lectures**
Unit – 5	Agreements and Treaties: GATT, TRIPS Agreements; Role of Madrid Agreement; Hague Agreement; WIPO Treaties; Budapest Treaty on international recognition of the deposit of microorganisms; UPOV & Brene conventions; Patent Co-operation Treaty (PCT); Indian Patent Act 1970 & recent amendments.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Study of components and design of a BSL-III laboratory
2. Filing applications for approval from biosafety committee
3. Filing primary applications for patents
4. Study of steps of a patenting process
5. A case study

Reference books

1. Private Power, Public Law: The Globalization of Intellectual Property RightsBy Susan K. SellCambridge University Press, 2000
2. Essentials of Intellectual Property: Law, Economics, and StrategyBy Alexander I. Poltorak; Paul J. Lerner Wiley, 2011 (2nd edition
3. M K Sateesh .Bioethics and Biosafety . Kindle Edition
4. Diane O. Fleming, Debra L. HuntBiological Safety: Principles and Practices, 4th Edition. ASM 2006
5. Shomini Parashar, Deepa GoelIPR, Biosafety and Bioethics Pearson India 2013

DSE6: Plant Pathology & Disease Management

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Developed basic concepts of causation of diseases in plants by the different types of microorganisms namely bacterial, fungal and viral.

Outcome 2. Knowledge of important plant diseases, their etiology, salient characteristics and control measures

Outcome 3. Developed skills to analyze the diseased plant samples in the laboratory and are able to identify the salient features of the disease-causing microbe and the lesions produced on the plant parts.

THEORY COURSE

(4 Credits)

Unit – 1	Concept of plant disease- definitions of disease, disease cycle & pathogenicity, symptoms associated with microbial plant diseases, types of plant pathogens, economic losses and social impact of plant diseases. Significant landmarks in the field of plant pathology- Contributions of Anton DeBary, Millardet, Burrill, E. Smith, Adolph Mayer, Ivanowski, Diener, Stakman, H.H. Flor,VanDer Plank, molecular Koch'spostulates .Contributions of eminent Indian plant pathologists.	**12 Lectures**
Unit – 2	Infection, invasion, colonization, dissemination of pathogens and perennation. Concepts of monocyclic, polycyclic and polyetic diseases, disease triangle &disease pyramid, forecasting of plant diseases and its relevance in Indian context. Microbial Pathogenicity**:** Virulence factors of pathogens: enzymes, toxins (host specific and non specific) growth regulators, virulence factors in	**12 Lectures**

	viruses (replicase, coat protein, silencing suppressors) in disease development. Effects of pathogens on host physiological processes(photosynthesis, respiration, cell membrane permeability, translocation of water and nutrients, plant growth and reproduction).	
Unit – 3	Genetics of Plant Disease***:*** Concept of resistance (R) gene and avirulence (avr) gene; gene for gene hypothesis, types of plant resistance: true resistance– horizontal & vertical, apparent resistance. Defense Mechanisms in Plant:Concepts of constitutive defense mechanisms in plants, inducible structural defenses (histological- cork layer, abscission layer, tyloses, gums), inducible biochemical defenses [hypersensitive response (HR), systemic acquired resistance (SAR), phytoalexins, pathogenesis related (PR) proteins, plantibodies, phenolics, quinones,oxidative bursts]	**12 Lectures**
Unit – 4	Principles & practices involved in the management of plant diseases by different methods, *viz.* regulatory - quarantine, crop certification, avoidance of pathogen, use of pathogen free propagative material. cultural - host eradication, crop rotation, sanitation, polyethylene traps and mulches chemical - protectants and systemic fungicides, antibiotics, resistance of pathogens to chemicals. biological - suppressive soils, antagonistic microbes-bacteria and fungi, trap plant; genetic engineering of disease resistant plants- with plant derived genes and pathogen derived genes	**12 Lectures**
Unit – 5	**Study of some important plant diseases giving emphasis on its etiological agent, symptoms, epidemiology and control.** White rust of crucifers-*Albugocandida*; Downy mildew of onion - *Peronospora destructor* Late blight of potato - *Phytophthorainfestans*; Powdery mildew of wheat – *Erysiphegraminis* Ergot of rye - *Clavicepspurpurea*; Black stem rust of wheat – *Pucciniagraministritici* Loose smut of wheat - *Ustilagonuda*; Wilt of tomato - *Fusarium oxysporum*f.sp.	**12 Lectures**

	lycopersici Red rot of sugarcane - *Colletotrichumfalcatum*; Early blight of potato - *Alternariasolani*; Angular leaf spot of cotton,bacterial leaf blight of rice, crowngalls, bacterial cankers of citrus; Aster yellow, citrus stubborn; Papaya ring spot,tomat oyellow leaf curl,banana bunchy top, rice tungro; Potato spindle tuber,coconut cadang cadang	

LAB. COURSE
(2 Credits)

Demonstration of Koch's postulates in fungal, bacterial and viral plant pathogens.

2. Study of important diseases of crop plants by cutting sections of infected plant material-*Albugo, Puccinia, Ustilago, Fusarium, Colletotrichum*

Reference Books

1. EldorA.Paul. SoilMicrobiology. EcologyandBiochemistry.VIEdition:Academic Press, (2007).
2. EugeneL. Madsen. Environmental Microbiology:FromGenomestoBiogeochemistry. IEdition,Wiley-BlackwellPublishing. (2008).
3. Agrios,G.N.Plant pathology. HarcourtAsiaPvt.Ltd. (2000).
4. Buchanan.B.B.,Gruissem, W.andJones,R.L Biochemistryand MolecularBiology ofPlants. I.K.International Pvt.Ltd. (2000). .
5. Mehrotra R S and Ashok Agrawal. Plant Pathology. Tata Mc Graw Hill ,6th reprint (2006).
6. K. S. Bilgrami, H. C. Dube. A textbook of modern pathology. 6th Edition,Vani Educational Books, a division of Vikas, (1984).
7. .Plant Pathology.Elsevier Science Publishing Co Inc 2005.George Nicholas Agrios
8. K.R. AnejaExperiments in Microbiology, Plant Pathology and Biotechnology . New Age Publications 2017

DSE7: Pharmaceutical Microbiology

Outcome 1. Acquired detailed knowledge of antimicrobial agents, their chemical nature, and mechanism of action and basis of resistance of microbes to these antimicrobials, formulations involving different antimicrobials, stabilization of formulations.

Outcome 2. Developed understanding of different types of disinfectants/antiseptics and their specific uses, and evaluation of their bactericidal and bacteriostatic actions; basic knowledge of cell cultures.

Outcome 3. Developed practical skills for testing pharmaceutical products for sterility testing and pyrogenicity testing using different methods

THEORY COURSE

(4 Credits)

Unit - 1	Antibiotics and Synthetic antimicrobial agents microbial resistance;therapeutic, prophylactic usage and adverse reactions;Antibiotic and Synthetic antimicrobial agents: Mechanism of action of antibiotics Inhibition of cell wall synthesis,nucleic acid and protein synthesis. β-lactam, aminoglycosides, tetracyclines, macrolides.Antifungal antibiotics: Griseofulvin. Antiviral drugs: Amantidines;Nucleoside analogues, interferons. Peptide antibiotics. Synthetic antibiotics: Sulphonamides Chloramphenicol; Quinolone Bacterial resistance to antibiotics;Penetration of antimicrobial agents (cellular permeability barrier, cellular transport system and drug diffusion).	**12 lectures**

Unit - 2	sources /types of microbial contaminants, assessment of microbial contamination and spoilage.Preservation of pharmaceutical products using antimicrobial agents, evaluation of microbial stability of formulations.	**12 lectures**
Unit - 3	Classification and mode of action of disinfectants. Factors influencing disinfection, antiseptics and their evaluation. For bacteriostatic and bactericidal actions Evaluation of bactericidal & Bacteriostatic agents. Sterility testing of products (solids, liquids, ophthalmic and other sterile products) according to IP, BP and USP.	**12 lectures**
Unit - 4	Designing of aseptic area, laminar flow equipments; study of different sources of contamination in an aseptic area and methods of prevention, clean area classification. Principles and methods of different microbiological assay. Methods for standardization of antibiotics, vitamins and amino acids. Assessment of a new antibiotic and testing of antimicrobial activity of a new substance. Safety profile of drugs (Pyrogenecity, Toxicity –hepato, - nephro, -cardio and -neurotoxicity) ;Toxicological evaluation of drug: LD50, Acute, subacute and chronic toxicity ;Mutagenecity (Ames test, micronucleus test), Carcinogenicity and Teratogenecity	**12 lectures**

<table>
<tr><td>Unit - 5</td><td>Growth of animal cells in culture, general procedure for cell culture, Primary, established and transformed cell cultures.Application of cell cultures in pharmaceutical industry and research.Molecular principles of drug targeting;Drug delivery system in gene therapy.

LAB COURSE
(2 credits)
1. Microbial Examination of sterile and Non Sterile Products
2. Bacterial Endotoxin Testing by Gel Clot Method
3. Test for Confirmation of Labeled LAL Reagent Sensitivity (LAL Test)
4. Antibiotic Potency Testing
5. Bioburden Estimation for Medical Devices
6. Determination of D value, Z value for heat sterilization in pharmaceuticals.
7. Chemical / Microbiological methods for the determination of Penicillin, Streptomycin, Griesofulvin
8. Prediction of binding site of macromolecules using MEDsuMo software</td><td>12 lectures</td></tr>
</table>

Reference Books

1. A Textbook of Pharmaceutical Microbiology Paperback (2018) by Pulak Mujumder, Sameer Rajan Sahoo Everest Publishing
2. A Textbook of Pharmaceutical Microbiology (2015) Mehra Prahlad Singh IK International Publishing
3. Pharmaceutical Microbiology (2015)by Sheth Z.PCBS Publisher
4. A.V.S.S. Sambamurty .A Textbook of Plant Pathology. IK International Publishing House 2009
5. 5.Nidhi Goel .Pharmaceutical Microbiology: A Textbook .Alpha Science Intl Ltd .2012
6. 5.Prahlad Singh Mehra .A Textbook of Pharmaceutical Microbiology .IK International Publications

DSE8: Instrumentation and Bio-techniques

Course learning outcomes: By the conclusion of this course, the students have -

Outcome 1. Developed understanding of principals, and applications of different microscopic and spectrophotometric methods.

Outcome 2. Developed understanding of principals, and applications of different separation techniques especially chromatographic, electrophoretic and centrifugation techniques.

Outcome 3. Skills in handling and use of light microscope, spectrophotometer and centrifugation equipment to study/analyze various microbiological samples.

THEORY COURSE
(4 Credits)

Unit – 1	Microscopy**:** Bright field and dark field microscopy, Fluorescence Microscopy, Phase contrast Microscopy, Confocal Microscopy, Electron Microscopy (Scanning and Transmission Electron Microscopy) and Micrometry.	**12 Lectures**
Unit – 2	Chromatography**:** Principles and applications of paper chromatography (including Descending and 2-D), Thin layer chromatography. Column packing and fraction collection. Gel filtration chromatography, ion- exchange chromatography and affinity chromatography, GLC, HPLC.	**12 Lectures**
Unit – 3	Electrophoresis: Principle and applications of native polyacrylamide gel electrophoresis, SDS- polyacrylamide gel electrophoresis, 2D gel electrophoresis, Isoelectric focusing, Zymogram preparation and Agarose gel electrophoresis.	**12 Lectures**
Unit – 4	Spectrophotometry**:** Principle and use of study of absorption spectra of biomolecules. Analysis of biomolecules using UV and visible range.	**12 Lectures**

	Colorimetry and turbidometry.	
Unit – 5	Centrifugation:Preparative and analytical centrifugation, fixed angle and swinging bucket rotors. RCF and sedimentation coefficient, differential centrifugation, density gradient centrifugation and ultracentrifugation.	**12 Lectures**

LAB. COURSE

(2 Credits)

Study of fluorescent micrographs to visualize bacterial cells.

Ray diagrams of phase contrast microscopy and Electron microscopy.

Separation of mixtures by paper/thin layer chromatography.

Demonstration of column packing in any form of column chromatography.

Separation of protein mixtures by any form of chromatography.

Separation of protein mixtures by Polyacrylamide Gel Electrophoresis (PAGE).

Reference books

1. Textbook Of Biophysical Chemistry by U N Dash Macmillan Publishers India (2006)
2. Biophysical chemistry by Nath, Nath and Upadhyay
3. Wilson& Walker.Principles andTechniquesinPractical Biochemistry. 5th Edition Cambridge University Press (2000).
4. Khan I A and Khan I A. Fundamentals of Biostatistics, Ukaaz Publications, (1994).MurphyD.B.
6. FundamentalofLightMicroscopy&Electron Imaging.1st Edition.Wiley-Liss.(2001).
7. David Plummer .An Introduction To Practical Biochemistry 2006

DSE9: Interdisciplinary Project: Microbes and Society

As per the guidance of the supervisors/ departmental management

Course learning outcomes: By the conclusion of this course, the student is capable to-

Outcome 1. Identify problems which are related to microorganisms and has a societal relevance; identify lacunae in knowledge and frame objective of the study, in consultation with the Mentor/Teacher/Academic Advisor.

Outcome 2. Design relevant experiments, conduct the experiments, record /collect data and analyze data.

Outcome 3**.Draw inferences from data and its presentation.**

The student is required to carry out a project requiring experimental work amounting to 6 hours per week. Final report is to be submitted in a standard format as follows:

(Introduction, Objectives, Material and Methods, Results, Discussion, and Bibliography).

DSE10 :Veterinary Microbiology

Course learning outcomes: By the conclusion of this course, the students have -

Outcome 1. Developed basic concepts of the causation of diseases by different types of microorganisms.

Outcome 2. Developed knowledge of the common diseases of microbial etiology for animals especially the domesticated animals and the vaccines available for animal immunization.

Outcome 3.Acquired skills on the laboratory identification of disease causing microbes and antibiotic sensitivity testing.

THEORY COURSE

(4 Credits)

Unit – 1	History of microbiology and introduction to the microbial world. Microorganisms and fermentation, Germ theory of diseases, Development of various Microbiological techniques and golden era of microbiology. Contributions of Antony von Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Alexander Fleming, Martinus W. Beijerinck, Sergei N. Winogradsky, Selman A. Waksman, Paul Ehrlich, Elie Metchnikoff, Edward Jenner.	12 Lectures
Unit – 2	Physiochemical and biological characteristics of microorganisms (including viruses).Introduction to oncogenic viruses. Types of oncogenic DNA and RNA viruses:Bacterial structure, Nutritional requirements of bacteria, Types of media, Physical conditions required for bacterial growth, Bacterial growth curve, methods of measurement of bacterial growth	12 Lectures
Unit – 3	Microbial techniques: Pure culture isolation: Streaking, serial dilution and plating methods; cultivation, maintenance and preservation/stocking of pure cultures; cultivation of anaerobic bacteria, . Buffers in culture medium. Cultivation of fungi, actinomycetes, yeasts, Cultivation of anaerobes. Optical and Electron microscope (Structure and function),	12 Lectures

Unit – 4	Sources and routes of infection, Transmission of pathogens, portals of entry of pathogen, Microorganisms and animal host interactions, Toxins(endo and exo)	12 Lectures
Unit – 5	Study of following animal diseases with respect to etiology, symptoms, mode of transmission, prophylaxis and control: Q fever FMD, swine flu, bird flu, Rabies, bovine tuberculosis, , Infections caused by Campylobacter, Salmonella Marek's, ranikhet, brucellosis, distemper. Common cattele diseas Bovine Respiratory Disease Complex (BRDC),Clostridial Disease, or "Blackleg" ,BRSV (Bovine Respiratory Syncytial Virus) BVD (Bovine Viral Diarrhea) (Infectious Bovine Rhinotracheitis), (Parainfluenza Type 3),Pasteurella haemolytica and Pasteurella multocida.	12 Lectures

LAB. COURSE

(2 Credits)

1. Staining: Gram staining and Acid fast staining, motility by Hanging drop method.

2. Study of following equipment including care and maintenance) :Optical microscope . Incubator, Hot air oven, Autoclave

3. Preparation of commonly used media, Inoculation of culture plates (streak and spread plate) and broth media.

4. Biochemical tests: Sugar fermentation, IMViC, catalase, Oxidase, etc.

5. Antibiotic sensitivity testing Using disc.(Gram positive and Gram negative bacteria)

Reference Books

1. Textbook of Veterinary Microbiology (2015) By Sharma S.N.Vikas Publishing
2. General Veterinary Microbiology - An introduction (2017) By R.P. Diwakar R.K. Diwakar Astral Publishing
3. Veterinary Microbiology and Microbial Disease (2011), 2nd Edition By P. J. Quinn, B. K. Markey, F. C. Leonard, P. Hartigan, S. Fanning, E. S. Fitzpatrick Wiley
4. N. Maclachlan Edward J Dubovi Fenner's Veterinary Virology 5th Edition Academic Press (2016)
5. G. R. Carter, Darla J. Wise.Essentials of Veterinary Bacteriology and Mycology, Wiley-Blackwell (2003)
6. P. J. Quinn, B. K. Markey, F. C. Leonard, P. Hartigan, S. Fanning, E. S. Fitzpatrick.Veterinary Microbiology and Microbial Disease. Wiley-Blackwell (2011)

GENERIC ELECTIVE COURSE (GEC)

GEC1: Microbial world & Diversity

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Has acquired a fairly good understanding of the Diversity of the microbes

Outcome 2. Has acquired a fairly good understanding of the activities/importance of microbes.

Outcome 3. Has acquired practical skills of handing microorganisms in the laboratory for study.

THEORY COURSE
(4 Credits)

Unit – 1	Introduction to microbial world, Physiochemical and biological characteristics; Characteristics of Acellular microorganisms (Viruses); Baltimore classification, general structure with special reference to viroids and prions. Binomial Nomenclature, Whittaker's five kingdom and Carl Woese's three kingdom classification systems and their utility. Difference between prokaryotic and eukaryotic microorganisms	**12 Lectures**
Unit – 2	General characteristics of Cellular microorganisms, types - archaebacteria, eubacteria, wall-less forms - MLO (mycoplasma and spheroplasts) with emphasis on distribution and occurrence, morphology, mode of reproduction and economic importance. Structure, reproduction and economic importance of Mycoplasma.	**12 Lectures**
Unit – 3	General concept of Phytoplanktons and Zooplanktons. Characteristics, occurrence, thallus organization and classification of Algae. Cyanobacteria - occurrence, thallus organization, cell ultra structure, reproduction and	**12 Lectur**

	economic importance. Applications of algae in agriculture, industry, environment and food.	**es**
Unit – 4	Historical developments in the field of Mycology including significant contributions of eminent mycologists. General characteristics of fungi including habitat, distribution, nutritional requirements, fungal cell ultra-structure, thallus organization and aggregation, mode of reproduction and Economic importance of fungi with examples in agriculture, environment, Industry, medicine and food.	**12 Lectures**
Unit – 5	General characteristics, structure, mode of reproduction and economic importance of Actinomycetes with special reference to *its application in medicine and industry*. General characteristics,occurrence,classificationstructure,reproductionandeconomicimportanceof Protozoa.	**12 Lectures**

LAB. COURSE (2 Credits)
1. .Microbiology Good Laboratory Practices and Bio-safety. 2. To study the principle and applications of important instruments (biological safety cabinets, autoclave, incubator, BOD incubator, hot air oven, light microscope, pH meter) used in the microbiology laboratory. 3. Preparation of laboratory Glass wares (Chemical washing, cleaning and drying). 4. Preparation of culture media (Liquid & solid).for bacterial cultivation. 5. Handling and care of laboratory equipment - Autoclave, Hot air oven, Incubator, pH meter, Highspeed centrifuge, Laminar airflow. 6. Sterilization of medium using Autoclave. 7. Sterilization of glassware using Hot Air Oven and assessment for sterility. 8. Sterilization of heat sensitive material by membrane filtration and assessment for sterility

9. Demonstration of the presence of microflora in the environment by exposing nutrient agar plates to air.
10. Observation of microorganisms - Bacteria, Cyanobacteria Protozoa, Fungi, Yeasts, and Algae from Natural habitats.
11. Study of common fungi, algae and protozoan using temporary mounts

Reference Books

1. Singh,R.P.GeneralMicrobiology.KalyaniPublishers, NewDelhi (2007).
2. Aneja, K.R. Experiments in Microbiology, Plant pathology and Biotechnology, Fourth edition, NewAge International publishers.
3. Dubey, R.C. and Maheshwary, D.K. Text book of Microbiology. S.chand and company (1999).
4. Powar, C.B. and Daginawal, H.F. General Microbiology. Vol-I and Vol- II, Himalaya Publishing House.
5. Chakraborty P. A Textbook Of Microbiology. New central book Agency (2005).
6. Prescott,M.J.,Harley,J.P.andKlein,D.A.Microbiology. 5th Edition WCB Mc GrawHill, New York, (2002).
7. Tortora,G.J., Funke,B.R.andCase,C.L.Microbiology:AnIntroduction. PearsonEducation,Singapore, (2004).
8. Alcomo, I.E. FundamentalsofMicrobiology.VIEdition, JonesandBartlettPublishers.Sudbury.Massachusetts, (2001).
9. Black J.G.Microbiology-Principlesand Explorations.JohnWiley&SonsInc.NewYork, (2002).
10. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
11. Willey,Sherwood,Woolverton. Prescott,Harley, and Klein's Microbiology McGraw-Hill publication
12. Tortora,Funke,Case. Microbiology.Pearson Benjamin Cummings.
13. JACQUELYN G. BLACK. Microbiology Principles and explorations. JOHN WILEY & SONS, INC.
14. Madigan,Martinko, Bender,Buckley,Stahl.Brock Biology of Microorganisms. Pearson
15. Tom Besty,D.C Jim Koegh.Microbiology Demystified McGRAW-HILL.

GEC2: Bacteriology and Virology

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Has acquired a fairly good understanding of the different types of bacteria and viruses.

Outcome 2. Has acquired a fairly good understanding of the structure and other salient characteristics of bacteria and viruses.

Outcome 3. Has acquired skills of visualizing bacteria by staining, using a microscope and culturing bacteria in microbiological media to describe the features of bacterial colonies.

THEORY COURSE

(4 Credits)

Unit – 1	Virology: Discovery of viruses, nature and definition of viruses, general properties, concept of viroids, virusoids, satellite viruses and Prions. Theories of viral origin; Structure of Viruses. Viral taxonomy- Classification and nomenclature of different groups of viruses. Diversity, classification of bacteriophages, lytic and lysogenic phages (lambda phage) concept of early and late proteins, regulation of transcription in lambda phage.	**12 Lectures**
Unit – 2	Modesofviraltransmission:Persistent,non-persistent,verticalandhorizontal.Salientfeaturesof viral Nucleic acid : Unusual bases (TMV,T4 phage), overlapping genes (ϕX174, Hepatitis Bvirus), alternate splicing (HIV), terminal redundancy (T4 phage), terminal cohesive ends (lambda phage), partial double stranded genomes (Hepatitis B), long terminal repeats (retrovirus), segmented (Influenza virus), and non-segmented genomes (picornavirus), capping and tailing (TMV) Viral multiplication and replication strategies: Interaction of viruses with cellular receptors and entry of	**12 Lectures**

	viruses.ReplicationstrategiesofvirusesasperBaltimoreclassification(phiX174,R etroviridae, Vaccinia, Picorna) , Assembly, maturation and release of virions	
Unit – 3	Bacteria: Cell size, shape and arrangement, glycocalyx, capsule, flagella, endoflagella, fimbriae and pili. Cell-wall: Composition and detailed structure of Gram-positive and Gram-negative cell walls, Archaebacterial cell wall, lipopolysaccharide (LPS), sphaeroplasts, protoplasts, and L-forms. Cell Membrane: Structure, function and chemical composition of bacterial and archaeal cell membranes. Cytoplasm- Ribosomes, mesosomes, inclusion bodies, nucleoid, genome and plasmids Endospore: Structure, formation, stages of sporulation.	**12 Lectures**
Unit – 4	Nutritional requirements in bacteria and nutritional categories; Culture media: natural and synthetic media, chemically defined media, complex media, selective, differential, indicator, enriched and enrichment media. Physical methods of microbial control: heat, low temperature, high pressure, filtration, desiccation, osmotic pressure, radiation. Asexual methods of reproduction, logarithmic representation of bacterial populations, phases of growth, calculation of generation time and specific growth rate	**12 Lectures**
Unit – 5	Aim and principles of classification,systematics and taxonomy,concept of species,taxa,strain; conventional, molecular and recent approaches to polyphasic bacterial taxonomy, evolutionary chronometers, rRNA oligonucleotide sequencing, signature sequences, and protein sequences. Differences between eubacteria and archaebacteria. Eubacteria**:** Morphology, metabolism, ecological significance and economic importance of Gram negative and Gram positive bacteria	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Preparation of different media: synthetic media, Complex media Nutrient- agar, McConkey agar, EMB agar.
2. Gram staining
3. Acid fast staining-permanent slide only.
4. Isolation of pure cultures of bacteria by streaking method.
5. Preservation of bacterial cultures by various techniques.
6. Estimation of CFU count by spread plate method/pour plate method.
7. Motility by hanging drop method.
8. Study of the structure of important animal viruses (rhabdo, influenza, paramyxohepatitis B and retroviruses)using models, videos, and electron micrographs
9. Study of the structure of important plant viruses (caulimo, Gemini, tobacco ringspot, cucumber mosaic and alpha-alpha mosaic viruses) using electron micrographs
10. Study of the structure of important bacterial viruses (ϕX174,T4,Ʒ) using electron micrograph.
11. Isolation and enumeration of bacteriophages (PFU) from water/sewage sample using double agar layer technique
12. Study of cytopathic effects of viruses using photographs

Reference books

1. Pelczar M., Chan E.C.S. and Krieg, N.R. Microbiology.Tata Mc Grew Hill Publishing Co. Ltd., New Delhi.
2. Stainier R.V., Ingraham, J.L., Wheelis, M.L. and Painter P.R. The Microbial World. Printice-Hall of India (Pvt.) Ltd., New Delhi.
3. Alexopoulus, C.J., Mims,C.W. and Blackwel, M, Introductory Mycology. John Wiley, New York.
4. Mehrotra, R.S. and K.R.Aneja An Introduction to Mycology. New Age International Press, New Delhi.
5. Webster, J. Introduction to fungi. Cambridge University Press. Cambridge, U.K. (1985).
6. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
7. Willey,Sherwood,Woolverton. Prescott,Harley, and Klein's Microbiology McGraw-Hill publication
8. Tortora,Funke,Case. Microbiology.Pearson Benjamin Cummings.
9. JACQUELYN G. BLACK. Microbiology Principles and explorations. JOHN WILEY & SONS, INC.
10. Madigan,Martinko, Bender,Buckley,Stahl.Brock Biology of Microorganisms. Pearson
11. Tom Besty,D.C Jim Koegh.Microbiology Demystified McGRAW-HILL

S. Jane Flint , Lynn W. Enquist , Vincent R. Racaniello , Anna Marie Skalka .Principles of Virology. ASM Press; (2008)

GEC3: Medical Microbiology and Immunology

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Has acquired a fairly good understanding of normal microflora of human body, common diseases caused by bacteria, viruses and other microbes.

Outcome 2. Understood the basic components of the immune system and how this system serve to protect the host against disease-causing microbes.

Outcome 3. Has acquired skills of handling microorganisms in the laboratory and study their characteristics.

THEORY COURSE

(4 Credits)

Unit – 1	Normal microflora of the human body: Importance of normal microflora, normal microflora of skin, throat, gastrointestinal tract, urogenital tract. Host pathogen interaction: Definitions - Infection, Invasion, Pathogen, Pathogenicity, Virulence, Toxigenicity, Carriers and their types, Opportunistic infections, Nosocomial infections. Transmission of infection, Pathophysiologic effects of LPS. Collection, transport and culturing of clinical samples, principles of different diagnostic tests (ELISA, Immunofluorescence, Agglutination based tests, Complement fixation, PCR, DNA probes).	**12 Lectures**
Unit – 2	List of diseases of various organ systems and their causative agents. Symptoms, mode of transmission, prophylaxis and control of the diseases caused by Streptococcus pyogenes, Haemophilus influenzae, Mycobacterium tuberculosis, Bacillus anthracis, Clostridium tetani, Treponema pallidum, Clostridium difficile, and the viruses causing Polio, Herpes, Hepatitis, Dengue, AIDS, influenza and Japanese encephalitis.	**12 Lectures**
Unit – 3	Study of following animal diseases with respect to etiology, symptoms, mode of transmission, prophylaxis and control: FMD, swine flu, bird flu, Rabies, bovine	**12 Lectures**

	tuberculosis, Marek's, Ranikhet, brucellosis, distemper.	
Unit – 4	Mycoses: Cutaneous mycoses: Tinea pedis (Athlete's foot) Systemic mycoses: Histoplasmosis Opportunistic mycoses: Candidiasis. Occurrence, habitat, morphology and reproduction of Protozoa. Structure and reproduction of important Protozoans- Entamoeba, Giardia, Trichomonas, Leishmania, Trypanosoma and Plasmodium.	**12 Lectures**
Unit – 5	Immune system:Structure and function of the cells, tissues and organs of immune system. Types of immunity - Humoral and cell-mediated, innate, acquired immunity. Complement system - function and pathways. Antigen-Antibody: types, properties. Hapten, adjutants, Immunoglobulins: Structure types, Properties and their function - Theory of antibody production. Antigen-Antibody Interactions, Agglutination, Precipitation, Complement fixation test. Hypersensitivity reactions; IgE mediated Type I Hypersensitivity, Antibody- mediated cytotoxic (Type II) Hypersensitivity, Immune complex mediated (Type III) Hypersensitivity, TDTH mediated (Type IV) Hypersensitivity.	**12 Lectures**
LAB. COURSE (2 Credits)		
• Identify bacteria (any three of *E.coli*, *Salmonella, Pseudomonas, Staphylococcus, Bacillus*) using laboratory strains on the basis of cultural, morphological and biochemical characteristics: IMViC, TSI, nitrate reduction, urease production and catalase tests • Studyofcompositionanduseofimportantdifferentialmediaforidentificationofbacteria:EMB Agar, McConkey agar, Mannitol salt agar, Deoxycholate citrate agar, TCBS • Study of bacterial flora of skin by swab method • Perform antibacterial sensitivity by Kirby-Bauer method • Study symptoms of the diseases with the help of photographs: Polio, anthrax, herpes,		

chickenpox, HPV warts, AIDS(candidiasis),dermatomycoses(ringworms)

- Study of various stages of malarial parasite in RBCs using permanent mounts.

Reference books

1. Bernard, Davis B. Dulbecco, Eisen and Ginsberg. Microbiology including immunology and molecular Genetics. 3rd Edition
2. Roitt I. Essential Immunology. 10th Ed. Blackwell Science.
3. Kuby. Immunology. 4th edition. W. H. Free man & company.
4. Ananthanarayan and Paniker. Text book of microbiology. University press. 8th edition
5. Pelczar, MJ Chan ECS and Krieg NR, Microbiology McGraw-Hill.
6. Willey,Sherwood,Woolverton. Prescott,Harley, and Klein’s Microbiology McGraw-Hill publication
7. Tortora,Funke,Case. Microbiology.Pearson Benjamin Cummings.
8. JACQUELYN G. BLACK. Microbiology Principles and explorations. JOHN WILEY & SONS, INC.
9. Madigan,Martinko, Bender,Buckley,Stahl.Brock Biology of Microorganisms. Pearson
10. Tom Besty,D.C Jim Koegh.Microbiology Demystified McGRAW-HILL.

GEC4: Industrial and Food Microbiology

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Has acquired a fairly good knowledge of how microbes are used in the fermentative production of organic acids, alcohols, enzymes, antibiotics and various foods in the industry.

Outcome 2. Has acquired knowledge of various physical parameters which affect production of industrial products by the microorganisms and the safety aspects of the production and use of these products.

Outcome 3. Has developed laboratory skills in producing alcohol and enzymes by fermentative process using bacteria/yeast; Laboratory skills of testing microbial load in milk.

THEORY
COURSE
(4 Credits)

Unit – 1	Brief history and developments in industrial microbiology. Types of fermentation processes -solid state, liquid state, batch, fed-batch and continuous Types of fermenters – laboratory, pilot-scale and production fermenters. Components of a typical continuously stirred tank bioreactor. Primary and secondary screening. Preservation and maintenance of industrial strains	**12 Lectures**
Unit – 2	Downstream processing - filtration, centrifugation, cell disruption, solvent extraction. Microbial production of industrial products - citric acid, ethanol and penicillin. Industrial production and uses of the enzymes - amylases, proteases, lipases and cellulases.	**12 Lectures**
Unit – 3	Ingredients used in fermentation medium - molasses, corn steep liquor, whey & Yeast extract Food as a substrate for microbial growth; Intrinsic and extrinsic parameters that affect microbial growth in food Microbial spoilage of food - milk, egg, bread and canned foods	**12 Lectures**

Unit – 4	Physical methods - high temperature, low temperature, irradiation, aseptic packaging Chemical methods - salt, sugar, benzoates, citric acid, ethylene oxide, nitrate and nitrite Food sanitation and control – HACCP	**12 Lectures**
Unit – 5	Fermented dairy products - yogurt, acidophilus milk, kefir, dahi and cheese Probiotics definition, examples and benefits. Food intoxication by *Clostridium botulinum* and *Staphylococcus aureus* Food infection by *Salmonella* and *E.coli*	**12 Lecture**

LAB. COURSE

(2 Credits)

1. Study of different parts of fermenter
2. Microbialfermentationsfortheproductionandestimation(qualitativeandquantitative)of:Enzymes: AmylaseandProtease; Amino acid: Glutamic acid; Organic acid: Citric acid; Alcohol: Ethanol
3. A visit to any educational institute/industry to see an industrial fermenter, and other downstream processing operations.
4. MBRT of milk samples and their standard plate count.
5. Alkaline phosphatase test to check the efficiency of pasteurization of milk.
6. Isolation of spoilage microorganisms from spoiled vegetables/fruits.
7. Preparation of Yogurt/Dahi.

Reference books

1. Nduka Okafor. Modern Industrial Microbiology and Biotecnology. 1st Edition. Science Publishers. (2007).
2. Waites, M.J., Morgan, N.L., Rockey, J.S. and Hington, G. Industrial Microbiology: An introduction. Blackwell science Publishers. (2002).Nduka Okafor, Benedict C. Okeke.Modern Industrial Microbiology and Biotechnology. CRC Press. (2017)W Clarke .Biotechnology : Industrial Microbiology A Textbook .CBS Publishers and Distributors(2016)

GEC5: Microbes in Sustainable Agriculture and Development

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Has acquired a fairly good understanding of microbes in the soil.

Outcome 2. Has developed a fairly good understanding of the use of microbes in sustainable agriculture namely role in biogeochemical recycling, nitrogen fixing, organic matter degradation, use as bio fertilizers, as bio pesticides, production of biofuels

Outcome 3.Has developed skills for growing microorganisms in the laboratory for the production of different enzymes by different microorganisms.

THEORY COURSE (4 Credits)

Unit – 1	Soil Microbiology**:** Soil as Microbial Habitat, Soil profile and properties, Soil formation, Diversity and distribution of microorganisms in soil. Microbial Activity in Soil and Green House Gases- Carbon dioxide, methane, nitrous oxide, nitric oxide – production and control	**12 Lectures**
Unit – 2	Mineralization of Organic & Inorganic Matter in Soil**:** Mineralization of cellulose, hemicelluloses, lignocelluloses, lignin and humus, phosphate, nitrate, silica, potassium	**12 Lectures**
Unit – 3	Microbial Control of Soil Borne Plant Pathogens**:** Biocontrol mechanisms and ways, Microorganisms used as biocontrol agents against Microbial plant pathogens, Insects, Weeds	**12 Lectures**
Unit – 4	Biofertilization,Phytostimulation,Bioinsecticides**:**Plantgrowthpromotingbateria,biofertilizers–symbiotic (*Bradyrhizobium, Rhizobium, Frankia*),	**12 Lectures**

	Non Symbiotic (*Azospirillum*, *Azotobacter*, Mycorrhizae, MHBs, Phosphatesolubilizers,algae), Novel combination of microbes asbiofertilizers, PGPRs	
Unit – 5	Secondary Agriculture Biotechnology**:** Biotech feed, Silage, Biomanure, biogas, biofuels – advantages and processing parameters. **GM crops:** Advantages, social and environmental aspects, Bt crops, golden rice, transgenic animals.	**12 Lectures**

LAB. COURSE
(2 Credits)

1. Isolation and purification of cyanobacteria, actinomycetes, fungi
2. Methods of isolation and identification of fungi by traditional methods Study of soil fungi
3. Staining and observation of plant pathogenic fungi.
4. Isolation of amylase producing microorganisms from soil
5. Isolation of protease producing microorganisms from soil
6. Isolation and Rhizobium and Azotobacter Nitrogen bacteria from soil.
7. Laboratory scale production of biofertilizers.
8. Isolation and characterization of plant growth promoting bacteria.
9. Splash liberation of fungal spores from diseased tissue.
10. Seed health testing by using Standard Blotter Method

Reference books

1. EldorA.Paul. SoilMicrobiology. EcologyandBiochemistry.VIEdition:Academic Press, (2007).
2. EugeneL. Madsen. Environmental Microbiology:FromGenomestoBiogeochemistry. IEdition,Wiley-BlackwellPublishing. (2008).
3. Agrios,G.N.Plant pathology. HarcourtAsiaPvt.Ltd. (2000).
4. Buchanan.B.B.,Gruissem, W.andJones,R.L Biochemistryand MolecularBiology ofPlants. I.K.International Pvt.Ltd. (2000). .
5. Mehrotra R S and Ashok Agrawal. Plant Pathology. Tata Mc Graw Hill ,6th reprint (2006).
6. K. S. Bilgrami, H. C. Dube. A textbook of modern pathology. 6th Edition,Vani Educational Books,

a division of Vikas, (1984).

7. K.R. Aneja .Experiments in Microbiology, Plant Pathology and Biotechnology . New Age Publications.2017

GEC6: Microbial Enzyme Technology

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1.Have acquired knowledge how microbes serve as a source for a large number of enzymes

Outcome 2. How these enzymes are produced in the laboratory, how their production is increased by different conditions and how the enzymes are purified.

Outcome 3. Practical skill for production and purification of enzymes; factors affecting microbial enzyme production; immobilization of enzymes.

THEORY COURSE (4 Credits)

Unit – 1	Basic concepts o fenzymes**:**Nomenclature,classification,methodsfordeterminationofenzyme activity. Isolation and purification of enzymes. Enzyme kinetics: Michaelis-Menten equation, effect of pH, substrate concentration, temperature and inhibitors. Isoenzymes and allosteric enzymes. Enzyme inhibition- competitive and non-competitive inhibition	**12 Lectures**
Unit – 2	Enzymes from microbial sources, large scale production of enzymes, recovery of enzymes, enzyme purification methods - enzyme precipitation, separation by chromatography, enzyme reactors.	**12 Lectures**
Unit – 3	Immobilized enzymes:Physical and chemical methods of immobilization, immobilization supports, kinetics of immobilized enzymes. Enzyme catalysis in apolar medium, reverse micellar entrapment of enzymes and its applications.	**12 Lectures**
Unit – 4	Application of enzymes:synthesis of chemicals using enzymes, food technology and medicine. Enzymes in diagnostic assays. Enzyme electrodes, immunoenzyme techniques.	**12 Lectures**

Unit – 5	Microbial toxins:Types, biochemical and molecular basis of toxin production, implications. Genetically engineered microbes, anti-HIV, anticancer, antifungal, antiplasmodial, anti- inflammatory compounds.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Isolation Purification of amylase from suitable culture: assay, Purification at least three steps, Determination of Km., Line Weaver Burk plot
2. Isolation Purification of cellulase from suitable culture: assay, Purification at least three steps, Determination of Km., Line Weaver Burk plot Factors affecting enzyme activity (pH, Temperature) Immobilisation of enzyme using calcium alginate
3. ELISA(demonstration)

Reference Books

1. Berg JM,Tymoczko JL,StryerL., Biochemistry. 6th Edition.Freeman (2006).
2. Prakash Singh Bisen, Anjana Sharma, Introduction to Instrumentation in Life Sciences, Taylor and Francis, (2012).
3. James Bailey and David Ollis, Fundamentals of Biochemical Engineering, 2nd edition, McGraw-Hill, (1986).
4. Casida LE, Industrial Microbiology, J. Wiley, (1968).
5. Chisti. Y.Encyclopedia of Bioprocess Technology, Vol-5, John Wiley and Sons, New York.
6. Michael L. Shuler and Fikret Kargi. Bioproccess Engineering: Basic Concepts, 2nd Edition. Prentice Hall. (2001).
7. **Fogarty**, W.M., **Kelly**, C.T. Microbial Enzymes and Biotechnology
8. Goutam Brahmachari .Biotechnology of Microbial Enzymes .Academic Press (2016)

GEC 7: Microbial Genetics and Molecular Biology

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Has acquired knowledge of gene, their expression and regulation of expression.

Outcome 2. Has acquired a fairly good understanding mechanisms of genetic exchange, mutations and their implications.

Outcome 3. Has developed practical skill for isolation of bacteria/plasmid DNA and its visualization in gel after separation by electrophoresis.

THEORY COURSE (4 Credits)

Unit – 1	Structures of DNA and RNA/Genetic Material**:** DNA structure, Salient features of double helix, Types of DNA, denaturation and renaturation, topoisomerases; Organization of DNA Prokaryotes, Viruses, Eukaryotes. RNA Structure. Replication of DNA: Bidirectional and unidirectionalreplication,semi-conservative,semi-discontinuousreplicationMechanismof DNA replication: Enzymes and proteins involved in DNA replication –DNA polymerases, DNA ligase, primase, telomerase – for replication of linear ends.	**12 Lectures**
Unit – 2	Gene Expression:Transcription - Definition, promoter - concept and strength of promoter. Transcriptional Machinery and Mechanism of transcription. Translation - Genetic code, Translational machinery, Charging of tRNA, aminoacyl tRNA synthetases, Mechanisms of initiation, elongation and termination of polypeptides.	**12 Lectures**
Unit – 3	RegulationofgeneExpression:Principlesoftranscriptionalregulation,regulationatinitiation withexamplesfrom*lac*and*trp*operons.**Mutation:**Mutationsandmutagenesis:Definitio	**12 Lectures**

	nand types of Mutations; Physical and chemical mutagens; Uses of mutations, DNA repair mechanisms	
Unit – 4	Mechanisms of Genetic Exchange:Transformation - Discovery, mechanism of natural competence Conjugation - Discovery, mechanism, Hfr and F' strains Transduction - Generalized transduction, specialized transduction	**12 Lectures**
Unit – 5	Plasmids and Transposable Elements:Property and function of plasmids, Types of plasmids. Prokaryotic transposable elements – Insertion Sequences, composite and non-composite transposons, Replicative and Non replicative transposition, Uses of transposons and transposition.	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Study of different types of DNA and RNA using micrographs and model / schematic representations
2. Study of semi-conservative replication of DNA through micrographs / schematic representations
3. Estimationofsalmonsperm/calfthymusDNAusingcolorimeter(diphenylaminere agent)orUV spectrophotometer (A260measurement)
4. Resolution and visualization of DNA by Agarose Gel Electrophoresis.
5. Resolution and visualization of proteins by Polyacrylamide Gel Electrophoresis (SDS-PAGE).
6. Study the effect of chemical (HNO2) and physical (UV) mutagens on bacterial cells
7. Study survival curve of bacteria after exposure to ultraviolet (UV)light
8. DemonstrationofBacterialTransformationandcalculationoftransformationefficiency.

Reference Books

1. BenjaminLewin, GeneVII, OxfordUniversityPress, (2000).
2. BruceAlberts,AlexanderJohnson,JulianLewis,MartinRaff,KeithRoberts,PeterWalter, Molecular biologyoftheCell, 4th Edition. Garland publishing Inc, (2002).
3. Darnell,LodishandBaltimore, MolecularCellBiology, ScientificAmericanPublishingInc. (2000).

4. Watson.J.D,Baker.T.A,Bell.S.P,Gann.A.Levine.M.Losick.R, Molecular BiologyofGene, 5th Edition.TheBenjamin/CummingsPub.Co.Inc. (2003).
5. DavidFrifielder,Stanely R.Maloy, Molecularbiologyand Microbialgenetics. 2nd Edition,JonesandBarlettPublishers. (1994).
6. BrownT.A., GeneCloningand DNA analysis. 2nd Edition,ASMpress. (2004).
7. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
8. GlickBR andPasternakJJ, MolecularBiotechnology, 2nd Ed.ASM press. (2003).
9. Uldis N.Streips,RonaldE.Yasbin.Modern Microbial Genetics.2nd EditionWiley-Liss,Inc. (2002).
10. Russel P J, Essential genetics, Blackwell Science Inc, 2 sub edition, (1987).
11. Gardner E J, Simmons M J and Snupstad DP, Principles of genetics, 8th edition John Wiley & Sons, (2006).
12. Larry Snyder , Wendy Champness Molecular Genetics of Bacteria, ASM Press; (2007)

GEC8: Genetic Engineering and Biotechnology

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Has acquired a fairly good knowledge of the tools and the methods for genetic engineering.

Outcome 2. Has acquired a fairly good understanding of how these tools and methods are employed in the laboratory for manipulation of DNA so as to make it relevant for biotechnological uses.

Outcome 3. Students can perform isolation of DNA, amplification of any gene by PCR and its analysis by gel electrophoresis.

THEORY
COURSE
(4 Credits)

Unit – 1	Introduction to genetic engineering:Milestones in genetic engineering and biotechnology Restriction modification systems: Mode of action, applications of Type II restriction enzymes in genetic engineering. DNA modifying enzymes and their applications: DNA polymerases. Terminal deoxynucleotidyl transferase, kinases and phosphatases, and DNA ligases	**12 Lectures**
Unit – 2	Cloning: Use of linkers and adaptors:Transformation of DNA: Chemical method, Electroporation**.** Methods of DNA, RNA and Protein analysis: Agarose gel electrophoresis, Southern - and Northern - blotting techniques, dot blot, DNA microarray analysis,SDS-PAGE, and Western blotting	**12 Lectures**
Unit – 3	Cloning Vectors**:** Definition and Properties Plasmid vectors: pBR and pUC series Bacteriophage lambda and M13 based vectors Cosmids, BACs, YACs Expression vectors: *E.coli*lac and T7 promoter-based vectors, yeast YIp, YEp and YCp vectors, Baculovirus based vectors, mammalian SV40-based expression vectors	**12 Lectures**
Unit – 4	DNA Amplification and DNA sequencing: PCR: Basics of PCR, RT-PCR, Real-Time PCR Genomic and cDNA libraries: Preparation and uses, Genome sequencing Sanger’s	**12 Lectures**

	method of DNA Sequencing: traditional and automated sequencing	
Unit – 5	Application of Genetic Engineering and Biotechnology**:** Gene delivery:Microinjection, electroporation, biolistic method (gene gun), liposome and viral-mediated delivery, *Agrobacterium* - mediated delivery. Products of recombinant DNA technology: Products of human therapeutic interest - insulin, hGH, antisense molecules. Bt transgenic - cotton, brinjal, flavosavo tomato, Gene therapy, recombinant vaccine, protein engineering	**12 Lectures**

LAB. COURSE

(2 Credits)

1. Isolation of Plasmid DNA from *E.coli*
2. Digestion of DNA using restriction enzymes and analysis by agarose gel electrophoresis
3. Ligation of DNA fragments
4. Interpretation of sequencing gel electropherograms
5. Designing of primers for DN Aamplification
6. Amplification of DNA by PCR
7. Demonstration of Southern blotting

Reference books

1. BenjaminLewin, GeneVII, OxfordUniversityPress, (2000).
2. BruceAlberts,AlexanderJohnson,JulianLewis,MartinRaff,KeithRoberts,PeterWalter, Molecular biologyoftheCell, 4th Edition. Garland publishing Inc. (2002).
3. Darnell,LodishandBaltimore, MolecularCellBiology, ScientificAmericanPublishingInc. (2000).
4. Watson.J.D,Baker.T.A,Bell.S.P,Gann.A.Levine.M.Losick.R, Molecular BiologyofGene, 5th Edition.TheBenjamin/CummingsPub.Co.Inc. (2003).
5. DavidFrifielder,Stanely R.Maloy, Molecularbiologyand Microbialgenetics. 2nd Edition,JonesandBarlettPublishers. (1994).

6. BrownT.A., GeneCloningand DNA analysis. 2nd Edition,ASMpress. (2004).
7. Sandy Primrose. Principles of Gene Manipulation and Genomics. 7th Ed., Blackwell Publishers. (2006).
8. GlickBR andPasternakJJ, MolecularBiotechnology, 2nd Ed.ASM press. (2003).
9. Uldis N.Streips,RonaldE.Yasbin.Modern Microbial Genetics.2nd EditionWiley-Liss,Inc.(2002).
10. Desmond S. T. Nicholl.An Introduction to Genetic Engineering.Cambridge University Press; (2008)

SKILL –BASED ELECTIVE COURSE (SEC)

SEC1: Microbial Quality Control in Food & Pharmaceutical Industries

(4 Credits)

Course learning outcomes: By the conclusion of this course, the students-

Learning Outcome 1. Have developed a very good understanding of practical aspects of microbiological safety, various detection methodologies and use of different microbiological media in food industries.

Learning Outcome 2. Have developed a very good understanding of practical aspects of microbiological safety, various detection methodologies and toxicological testing of products in the pharmaceutical industries.

Unit – 1	Microbiological Laboratory and Safe Practices:Good laboratory practices - Good laboratory practices, Good microbiological practices. Biosafety cabinets – Working of biosafety cabinets, using protective clothing, specification for BSL- 1, BSL-2, BSL-3. Discarding biohazardous waste – Methodology of Disinfection, Autoclaving & Incineration	**12 Hours**
Unit – 2	Determining Microbes in Food / Pharmaceutical Samples: Culture and microscopic methods - Standard plate count, Most probable numbers, Direct microscopic counts, Biochemical and immunological methods: Limulus lysate test for endotoxin, gel diffusion, sterility testing for pharmaceutical products	**12 Hours**
Unit – 3	Molecular methods to determine microbes in samples- Nucleic acid probes, PCR based detection, biosensors. Enrichment culture technique, Detection of specific microorganisms - on XLD agar,	**12 Hours**

	Salmonella Shigella Agar, Manitol salt agar, EMB agar, McConkey Agar, Saboraud Agar	
Unit – 4	Ascertaining microbial quality of milk by MBRT, Rapid detection methods of microbiological quality of milk at milk collection centres (COB, 10 min Resazurin assay)	**12 Hours**
Unit – 5	HACCP for Food Safety and Microbial Standards**:** Hazard analysis of critical control point (HACCP) - Principles, flow diagrams, limitations Microbial Standards for Different Foods and Water – BIS standards for common foods and drinking water	**12 Hours**

Reference Books

1. Quality Control in the Food Industry V1, S Herschdoerfer,ISBN**:** 9780323152068,**:** Academic Press, 1967

2. Principles of Sensory Evaluation of Food- 1965 MA Amerine, RM , Pangborn and EB Roessler, Elsevier.

SEC2: Microbial Diagnostics and Public Health

(4 Credits)

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Have developed a very good understanding of practical aspects of collection of different clinical samples, their transport, culture and examination by staining, and molecular and immunological diagnostic methods for diagnosis of microbial diseases.

Outcome 2. Have developed a very good understanding of practical aspects of antibiotic sensitivity testing, water and food testing skills using kits available in the market.

Unit – 1	Importance of Diagnosis of Diseases:Bacterial, Viral, Fungal and Protozoan Diseases of various human body systems, Disease associated clinical samples for diagnosis.	**06 Hours**
Unit – 2	Collection of Clinical Samples **:**How to collect clinical samples (oral cavity, throat, skin, Blood, CSF, urine and faeces) and precautions required. Method of transport of clinical samples to laboratory and storage.	**06 Hours**
Unit – 3	Direct Microscopic Examination and Culture.Examination of sample by staining - Gram stain, Ziehl-Neelson staining for tuberculosis, Giemsa-stained thin blood film for malaria. Preparation anduseofculturemedia-Bloodagar,Chocolateagar,Lowenstein-Jensenmedium,MacConkey agar, Distinct colony properties of various bacterial pathogens.	**06 Hours**
Unit – 4	Serological and Molecular Methods:Serological Methods - Agglutination, ELISA, immunofluorescence, Nucleic acid based methods - PCR, Nucleic acid probes. Kits forRapid Detection of Pathogens:Typhoid, Dengue and	**06 Hours**

	HIV, Swine flu.	
Unit – 5	Testing for Antibiotic Sensitivity in Bacteria: Importance, Determination of resistance/sensitivityofbacteriausingdiscdiffusionmethod,Determinationofminimal inhibitory concentration (MIC) of an antibiotic by serial double dilution method	**06 Hours**

Reference books

1. Ananthanarayan R and Paniker CKJ. Textbook of Microbiology. 7th Edition. University Press Publication. (2005).

SEC3: Human Microbial Disease Management

(4 Credits)

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Have developed a very good understanding of practical aspects diagnosis of common human infections.

Outcome 2. Have developed a very good understanding of preventive measures for human infections by the use of antibiotics and vaccines.

Unit – 1	Human Diseases:Infectious and non-infectious diseases, microbial and non-microbial diseases, Deficiency diseases, occupational diseases, Incubation period, mortality rate, nosocomial infections Sign and Symptoms of common diseases.	**12 Hours**
Unit – 2	Microbial diseases**:**Respiratorymicrobialdiseases,gastrointestinalmicrobialdiseases,Nervous system diseases, skin diseases, eye diseases, urinary tract diseases, Sexually transmitted diseases: Types, route of infection, clinical systems and general prevention methods, study of recent outbreaks of human diseases (SARS/ Swine flu/Ebola) – causes, spread and control, Mosquito borne disease – Types and prevention.	**12 Hours**
Unit – 3	Therapeutics of Microbial diseases **:**Treatment using antibiotics: beta lactam antibiotics (penicillin, cephalosporins), quinolones, polypeptides and aminoglycosides**.** Judicious use of antibiotics, importance of completing antibiotic regimen, Concept of DOTS, emergence of antibiotic resistance, current issues of MDR/XDR microbial strains.	**12 Hours**
Unit – 4	Treatment using antiviral agents: Amantadine, Acyclovir, Azidothymidine. Concept of HAART.	**12 Hours**

	Vaccines: Importance, types, vaccines available against microbial diseases, vaccination schedule (compulsory and preventive) in the Indian context.	
Unit – 5	Prevention of Microbial Diseases**:** General preventive measures, Importance of personal hygiene, environmental sanitation and methods to prevent the spread of infectious agents transmitted by direct contact, food, water and insect vectors.	**12 Hours**

Reference Books

1. Ananthanarayan R and Paniker CKJ. Textbook of Microbiology. 7th Edition. University Press Publication. (2005).
2. Brooks GF, Carroll KC, Butel JS and Morse SA. Jawetz, Melnick and Adelberg's Medical Microbiology. 24th edition. McGraw Hill Publication. (2007).
3. Goering R, Dockrell H, Zuckerman M and Wakelin D. Mims Medical microbiology. 4th edition. Elsevier. (2007).
4. Drexler M; What You Need to Know About Infectious Disease.National Academies Press (US); 2010.

SEC4: Mushroom Cultivation & Trading

(4 Credits)

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Have developed a very good understanding of nutritional aspects and commercial use of mushrooms for human consumption.

Outcome 2. Have developed a very good understanding of practical cultivation of mushrooms, management of diseases affecting mushrooms, mushroom harvesting and various avenues for using it into an entrepreneurship

Unit – 1	Introduction**:** Morphology, Classification and identification of edible & non-edible/poisonous mushroom. Nutritional and Medicinal value of mushroom, Scope of mushroom cultivation.	**12 Hours**
Unit – 2	Structure & Life cycle:Button mushroom (Agaricus bisporus), Milky mushroom (Calocybe indica), Oyster mushroom (Pleurotus sajor caju) and paddy straw mushroom (Volvariellavolvcea). Breeding and genetic improvement of mushroom strains.	**12 Hours**
Unit – 3	Principles & Requisites**:** Sterilization and disinfections of substrates, Pasteurization of different substrates, Isolation, growth media, Spawns production and their maintenance.	**12 Hours**
Unit – 4	Techniques of Cultivation: Structure and construction of mushroom house, layout of Traditional and Greenhouse method. Multiplication of spawn, Composting, bed and polythene bag preparation, spawning - casing – cropping	**12 Hours**
Unit – 5	Cultivation management**:** Insect pests, fungal competitors and other	**12 Hours**

	important diseases. pest management-chemical control Harvest and Post harvest technology- freezing, dry freezing, drying, canning and entrepreneurship.	

Reference Books

1. Handbook on Mushrooms by Bahl N.

2. Benjamin Hirst Mushrooms: A Beginners Guide to Home Cultivation Paperback (20150

3. V. N. Pathak .Mushroom Production and Processing Technology IST Edition Hardcover – 2011

4. Eiri Staff Hand Book of Mushroom Cultivation, Processing and Packaging Paperback – Import, 2007

SEC5: Food Fermentations and Domestic Application

(4 Credits)

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Have developed a very good understanding of practical aspects commercially produced food and fermentative products.

Outcome 2. Have developed a very good understanding of practical use of microbiology for better production of home based food and fermentation products for day to day use

Unit – 1	Fermented Foods**:** Definition, types, advantages and health benefits, fermented foods used by Common public, domestication.	**12 Hours**
Unit – 2	Milk Based Fermented Foods**:** Dahi, Yogurt, Buttermilk (Chach) and cheese: Preparation of inoculums, types of microorganisms and production process.	**12 Hours**
Unit – 3	Grain Based Fermented Foods**:** Soy sauce, Bread, Idli and Dosa: Microorganisms and production process, Preparation and preservation.	**12 Hours**
Unit – 4	Vegetable Based Fermented Foods**:** Pickels, Saeurkraut: Microorganisms and production process. Preparation and preservation methods.	**12 Hours**
Unit – 5	Fermented Meat and Fish:Types, microorganisms involved, fermentation process Probiotic Foods:Definition, types, microorganisms and health benefits	**ours**

Reference books

1. Stanbury, PF., Principles of Fermentation Technology. Whittaker, A and Hall, S.J

2nd Edition. Pergamon Press (1995).

2. Banwart, GJ. Basic Food Microbiology. CBS Publishers and Distributors, Delhi. (1989).
3. Hobbs BC and Roberts D. Food poisoning and Food Hygiene. Edward Arnold (A division of Hodder and Stoughton) London.
4. Dolle Michaell P.. Food Microbiology: Fundamentals and Frontiers.
5. Joshi. Biotechnology: Food Fermentation Microbiology, Biochemistry and Technology. Volume 2.
6. John Garbult. Essentials of Food Microbiology. Arnold International.
7. John C. Ayres. J. Orwin Mundt. William E. Sandinee. Microbiology of Foods. W.H. Freeman and Co.
8. E. M. T. El-Mansi (Editor), C. F. A. Bryce (Editor), Arnold L. Demain (Editor), & 1 More Fermentation Microbiology and Biotechnology Hardcover CRC Press 2012

SEC6: Microbial Products – Bio-fertilizer & Bio-pesticides **(4 Credits)**		
Course learning outcomes: By the conclusion of this course, the students- **Outcome 1**. Have developed a very good understanding of practical aspects of production of biofertilizers. **Outcome 2**. Have developed a very good understanding of practical aspects of the production of biopesticides/bioinsecticides.		
Unit – 1	Biofertilizers:General account of the microbes used as biofertilizers for various crop plants and their advantages over chemical fertilizers. Symbiotic N2 fixers: *Rhizobium* - Isolation, characteristics, types, inoculum production and field application, legume/pulses plants *Frankia* - Isolation, characteristics, Alder, Casurina plants, non-leguminous crop symbiosis**.**	**12 Hours**
Unit – 2	Cyanobacteria as bio-fertilizers- Isolation, characterization, mass multiplication, Role in rice cultivation, Crop response, field application. Non - Symbiotic Nitrogen Fixers.Free living *Azospirillum*, *Azotobacter*-free isolation, characteristics, mass inoculums, production and field application	**12 Hours**
Unit – 3	Phosphate Solubilizers **:**Phosphate solubilizing microbes - Isolation, characterization, mass inoculum production, field application. PGPR – Isolation and Characterization; mass production and application.	**12 Hours**
Unit – 4	Mycorrhizal Bio-fertilizers**:** Importance of mycorrizal inoculum, types of mycorrhizae and associated plants, Mass inoculum production of VAM,	**12 Hours**

	field applications of Ectomycorrhizae and VAM.	
Unit – 5	Bioinsecticides **:**General account of microbes used as bioinsecticides and their advantages over synthetic pesticides, *Bacillus thuringiensis*, production, Field applications, Viruses – cultivation and field applications.	**12 Hours**
	Reference Books 1. EldorA.Paul. SoilMicrobiology. EcologyandBiochemistry.VIEdition:Academic Press, (2007). 2. EugeneL. Madsen. Environmental Microbiology:FromGenomestoBiogeochemistry. IEdition,Wiley-BlackwellPublishing. (2008). 3. Agrios,G.N.Plant pathology. HarcourtAsiaPvt.Ltd. (2000). 4. Buchanan.B.B.,Gruissem, W.andJones,R.L Biochemistryand MolecularBiology ofPlants. I.K.International Pvt.Ltd. (2000). . 5. Mehrotra R S and Ashok Agrawal. Plant Pathology. Tata Mc Graw Hill ,6th reprint (2006). 6. K. S. Bilgrami, H. C. Dube. A textbook of modern pathology. 6th Edition,Vani Educational Books, a division of Vikas, (1984). 7. Shalini Suri .Biofertilizer and Biopesticide Aph Publishing Corporation (2011)	

SEC7: Microbiological Analysis of Air, Water & Soil to Pollution Control

(4 Credits)

Course learning outcomes: By the conclusion of this course, the students-

Outcome 1. Have developed a very good understanding and skills of the analysis of air, water and soil.

Outcome 2. Have developed a very good understanding of how analysis of water, air and soil contribute to control of environmental pollution.

Unit – 1	Aero- microbiology:Bioaerosols, Air borne microorganisms (bacteria, Viruses, fungi) and their impact on human health and environment, significance in food and pharma industries and operation theatres, allergens.	**12 Hours**
Unit – 2	Bioaerosol sampling, air samplers, methods of analysis, CFU, culture media for bacteria and fungi, Identification characteristics .	**12 Hours**
Unit – 3	Water- microbiology: Water borne pathogens, water borne diseases. Sample Collection, Treatmentandsafetyofdrinking(potable)water,methodstodetectpotabilityof water samples: (a) standard qualitative procedure: presumptive/MPN tests, confirmed and completed tests for faecal coliforms (b) Membrane filter technique and (c) Presence/absence tests	**12 Hours**
Unit – 4	**Control Measures**: Fate of bioaerosols, inactivation mechanisms – UV light, HEPA filters, desiccation, Incineration. Precipitation, chemical disinfection, filtration, high temperature, UV light	**12 Hours**
Unit – 5	Soil- microbiology**:** Soil borne pathogens, soil borne diseases, Sampling of soil, sample collection	**12 Hours**

	and analysis. Isolation and identification of pathogens. Soil testing methods. Soil treatment.	
	Reference books- 1. Medigan, M.T., Martinko, J. M. and Parker, J. Brock Biology of Microorganisms. Pearson Education Inc. , New York 2. Alexander, M John. Microbial ecology. Wiley & Sons, Inc., New York. 3. Alexander, M John. Introduction to soil microbiology.Wiley & Sons Inc., New York. 4. Barker, KH, and Herson, D.S. Bioremediation. Mc Craw Hill Inc., New York. 5. Chapelle, F.H. *Ground Water Microbiology and Geochemistry*. New York: John Wiley & Sons, 2000. 6. Droste, R. L. *Theory and Practice of Water and Wastewater Treatment.* New York: John Wiley & Sons, 1996. 7. K.R. Aneja. Laboratory Manual of Microbiology and Biotechnology New Age Publications.2014	

SEC8: Interactions with Entrepreneurs in Microbial Technology and startups (4 Credits)
Course learning outcomes: By the conclusion of this course, the students- **Outcome 1**. Have developed a very good understanding of areas where Microbial Technology has the potential for possible commercialization. **Outcome 2**. Have developed a preliminary understanding of how a certain microbial technology may be further developed for initiating startup and developing it into a commercial enterprise
After interaction with experts from microbial biotechnology related industries / enterprises/ startups, the students would submit a short report and bring out innovations, novel ideas or the further improvements related to products being produced by such organizations

*ON LINE COURSE (OLC) Any Two through MOOCS available on NPTEL / SWAYAM		
OLC 1:	Applied Environmental Microbiology	(NPTEL)
OLC 2:	Biochemistry	(NPTEL)
OLC 3:	Fundamental of Microbiology	(NPTEL)
OLC 4:	Food Microbiology and Safety	(SWAYAM)
OLC 5:	Industrial Microbiology	(SWAYAM)

*These online courses which are already available on NPTEL / SWAYAM are broadly equivalent to courses of Microbiology in terms of content and Credit hours.

7. Teaching learning processes:

The teaching learning processes incorporate a variety of modes and a regular use of ICT. These are listed below:

1. **Classroom Teaching** for topics which are intensely information-based. This a very regular feature of all the courses in Microbiology
2. **Power Point slides** for topics which involve information related to intricate biological pathways such as metabolic pathways in bacteria and other microorganisms.

   Use of Power Point presentations are also made whenever the lectures are to be summarized in a crisp and pointwise manner to highlight salient / important conclusions from the topics.
3. **Classroom Discussions** are a regular feature while teaching. The students are drawn into impromptu discussions by the teacher during the process of teaching.
4. **Video Displaying**, both real-time and animations, are used for topics which require 3D dimensional viewing of the biological mechanisms to drive the point home. These have proved to be very helpful while teaching concepts of molecular biology like DNA replication, transcription and translation. These are also used to convey complexities of antigen-antibody interactions and generation of antibody diversity during the teaching of Immunology.
5. **Model Making** is also used especially for understanding and building a perception of the students for the structures of viruses which cannot be seen by a light microscope and can be seen only under expensive equipment like electron microscopes.
6. **Laboratory Practical** are an integral part of every course included in UG programme in Microbiology. The is also a daily affair for UG students of Microbiology.
7. **Problem Solving** is encouraged during the laboratory work.
8. **Group Activity** as well as discussions with the laboratory supervisor/ among the students themselves/ Mentor is also encouraged during laboratory work.

9. **Project Work** is included in the programme where students work individually or in groups to design experiments to solve/answer a problem suggested by the Mentor or identified by the students in consultation with the Mentor. The students are mentored regularly during the duration the project is in progress.

10. **Presentations by the Students** are regularly done. The students are mentored in presentation of data, interpretation of data and articulation with the students/teachers/Research Scholars during their presentation.

11. **Presentation by Experts** in different specialties of Microbiology are arranged to broaden the horizons of the students.

12. **Interaction with Experts** is also encouraged during/after presentations to satisfy/ignite curiosities of the students related to developments in the different ares of Microbiology.

13. **Visit to Industries/Laboratories** related to Microbiology like fermentation, food, diagnostics etc. are organized to acquaint the students with real-life working environments of the professional microbiologists with a view to broaden their perspective of the subject of Microbiology

8. Assessment Tasks:

It is important that the students of UG Microbiology program achieve the desired results in terms of the learning outcomes to be professionally sound and competitive in a global society. Achieving the desired learning outcomes is also imperative in terms of job employment leading to a happy and prosperous individual further leading to a happy and prosperous family and thereby a happy and prosperous society or nation. The assessments tasks are pivotal to get an authentic feedback for the teaching learning process and for mid-course corrections and further improvements in future. The assessment tasks are carried out at various stages of the duration of the UG Microbiology programme like Mid-term assessments, End-term assessments, Semester examinations, Regular assessments, viva-voce etc. The assessment tasks are listed below:

1. **Multiple Choice Questions (MCQ)** are one of the predominant form of assessment tasks. This task is used during all kinds of term and semester examinations.
2. **Short-AnswerQuestions** during term and semester examinations are used to assess the ability of the student to convey his thoughts in a coherent way where prioritization of the information in terms of their significance is tested.
3. **Surprise Quizzes** are regularly used during continuous assessment while the teaching learning process is continuing which prepares the student to quickly recall information or quickly analyze a problem and come up with proper solutions.
4. **Visual/Pictorial Quizzes** are used to sharpen the comprehension of the students after looking at all the components of a system.
5. **Impromptu Opinions** on microbiological problems are sought from student during regular teaching learning which help them to think quickly in a given context. This help build their ability to come up with solutions to problems which the students might not have confronted previously.
6. **Problem Solving** question are generally given during the laboratory work.
7. **Data Interpretation** is also another assessment task which is used to develop analytical skills of the students. This assessment is used during laboratory work as well as during conduction of project work.
8. **Analytical Skills** are assessed during work related to several experiments like enzyme kinetics, growth of bacteria and bacteriophages, mutation frequencies.
9. **Paper/ Project presentations** are used to assess the articulation skills of the student. These are carried out both during the duration of the teaching learning processes as well as during end-Semester examinations.
10. **Report Writing** is used to assess the keenness of the students for details related to microbiology while visiting laboratories / industries as students invariably are required to submit a report after such visits.
11. **Assignment Writing** are used to assess the writing abilities of the students during mid-term vacations.
12. **Viva-voce** during the laboratory working hours and during laboratory examination are used to assess the over-all knowledge and intelligence of the students.

9. Key Words:

Microbiology, Teaching, Learning outcomes, Curriculum, Curriculum Framework, Programme outcomes, Course outcomes, UG Programme, Undergraduate programme, Teaching learning processes, Assessment Tasks, Evaluation Tasks, Online Courses, MOOCS, NPTEL, SWAYAM, UGC, India, Higher Education Institutions, HEI

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Learning Outcomes based Curriculum Framework (LOCF)
for
(ZOOLOGY)
Undergraduate Programme
2020

ज्ञान-विज्ञान विमुक्तये

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.

DPSingh

New Delhi
30th July, 2019

(Prof. D. P. Singh)
Chairman
University Grants Commission

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9. Teaching-Learning Process (may be expanded keeping in view needs and outcomes

Preamble

Institutional infrastructures of colleges and universities within the country are incomparable and uneven, and they function with an additional variation of adopting different road maps for teaching and learning process. Thus, we have different syllabi, teaching methods, hands-on-training, and different learning outcomes. Introducing uniformity, whenever and wherever tried, has obviously not worked with the desired outcome. Added to this, failure to keep pace with the advancing knowledge base, half-hearted engagement and integration with other disciplines, and poor-transfer of skill sets to the students to negotiate efficiently with the changing needs, have made it essential to graduate from incremental inputs to syllabi revisions alone, to the use of disruptive approaches to reshape the subject-specific course structures, with measurable learning outcomes. The approach, if adopted, is bound to generate opinions of teachers and students alike to resist the change. However, the intention is to understand the subject of Zoology in the evolving biological paradigm in modern times; where, living beings need to be understood at the level of atomic interactions; and comparative systems of organisms need to be studied through the prism of integrated chemical, physical, mathematical and molecular entities to appreciate the inner working of different organisms at morphological, cellular, molecular, interactive and evolutionary levels. The syllabi could be shaped with a customised approach depending on the institutional infrastructure and geographical location, yet it should cater, in principle, to the expected learning outcomes more or less uniformly. For example, in diverse geographical domains with diverse skill sets, examples illustrated in detail for teaching and hands on exposure and field work could differ by involving the study of available species across the ladder of evolution, yet the comparative biology taught should provide a uniform level of understanding of the subject. After all, the purpose is to understand inner working of living-beings by comparing various systems within invertebrates and vertebrates i.e., from a single cell protozoan to multicellular humans, and develop a comprehensive understanding and appreciation of the differences through ICT tools and well-designed hands on practical exposures along with the field work. Added to this, if the same principle is followed to understand different phyla through the ladder of evolution and compare cardinal features for classification involving both morphological and molecular tools, along with associated field and lab work, the final product would be better trained without rote learning. Diversity in the life forms need to be understood by a Zoologist for its socio-economic capital, in case a student is interested in entrepreneurship, through applied aspects of Zoology; and by a careerresearcher as a ladder towards multiscale hierarchical systems, where chemical and physical principles would apply from molecules to self-assembled and organized organisms. The vibrancy to synthesize out of the knowledge gained and come out with disruptive outcomes, would define the learning outcomes of the future UG and PG students.

Apart from the above mentioned attributes expected of a UG/PG student related to the subject area of Zoology to be studied in an integrated and cross-disciplinary manner with a comprehensive understanding of all living systems, their relationship with the eco-system, and unravelling of their application value; the scale, character and rigour of which may vary from one institution to the other, it would, however, be mandatory to bring in uniformity in the learning outcomes with respect to the 'broad-range skill sets' related-to-the-discipline of the study and the 'Social skills'. Within the broad-range skill sets related to the discipline, what would be required is to impart and assess the quality of critical thinking, analytical and scientific reasoning, reflective thinking, information and digital literacy, and problem-solving capacity. These are part of the defined characteristic attributes to be demonstrated by a UG/PG in any discipline, as defined by the Core Committee on LOCF of UGC. On similar lines, what is expected of the social skills is to imbibe values for cooperative team work, moral and ethical awareness and reasoning, multicultural competence, leadership readiness and qualities and self- directed and lifelong learning attitude. Again, this has been a general guideline defined by the UGC Core Committee. It is obvious all of us together need to meet the challenge to bring in these attributes within each subject area of study, in the present case the subject of Zoology.

As regards the fine nuances of how to organize the course structure in Zoology and Aquaculture (the latter being a part of the subject of Applied Zoology, may not necessarily require separate emphasis) within the framework of expectations of the learning outcome, I provide a few steps of specific details for general debate and course corrections, wherever required.

Specific Details:

Background: Students should be equipped to identify the major groups of organisms, discuss the basis of their biodiversity and draw parallels with their phylogenetic relationship, using well thought cardinal features of classification on the basis of morphology and molecular information wherever available. This principle of comparative biology should be followed in understanding comparative anatomy, physiology and other functions for all in the hierarchy of animal evolution, instead of dealing with each phylum/order/species and each system as a stand-alone. This shall allow the student to gain comprehensive knowledge about different animal species in one go, appreciating the differences and similarities, thereby achieving proficiency in handling them experimentally or for research purposes. This would also reduce the burden of teaching on mentors, though initially a little hard work to shape the contents of the curriculum is required. Teachers would need to be trained for the same as well for a uniform approach to deliver and communicate.

A comprehensive knowledge of structure-function relationship at the level of gene, genome, cell, tissue, organ, and systems, through development would further add to the knowledge base and the learning outcome in terms of editing of genes and genomes for industrial application and research purposes. Short dissertations could be designed around these problems to give them hands-on-training and equip them with skill sets of use in future, in the areas of applied aspects of Zoology, including Aquaculture.

Details of the course content in an integrated fashion to cut down on some of the individual lectures would be designed by the members of the committee for further feedback to shape the syllabi better for both UG and PG students, so as to be monitored for the outcomes through the innovative processes of learning efficiently and effectively.

1. **Introduction**

Zoology deals with the study of animal kingdom specially the structural diversity, biology, embryology, evolution, habits and distribution of animals, both living and extinct. As it covers a fascinating range of topics, the modern zoologists need to have insight into many disciplines. The learning outcomes-based curriculum framework for a B.Sc. degree in Zoology is designed to cater to the needs of students in view of the evolving nature of animal science as a subject. The framework is expected to assist in the maintenance of the standard of Zoology degrees/programmes across the country by reviewing and revising a broad framework of agreed expected graduate attributes, qualification descriptors, programme learning outcomes and course-level learning outcomes. The framework, however, does not seek to bring about uniformity in syllabi for a programme of study in Zoology, or in teaching-learning process and learning assessment procedures. Instead, the framework is intended to allow for flexibility and innovation in programme design and syllabi development, teaching-learning process, assessment of student learning levels.

2. **Learning Outcomes based approach to Curriculum Planning**

The courses should be delivered in terms of concepts, mechanisms, biological designs & functions and evolutionary significance cutting across organisms at B.Sc. level. These courses should be studied by students of all branches of biology. Both chalk and board, and PowerPoint presentations can be used for teaching the course. The students should do the dissertation/ project work under practical of different courses, wherever possible.

The students are expected to learn the courses with excitements of biology along with the universal molecular mechanisms of biological designs and their functions. They should be able to appreciate shifting their orientation of learning from a descriptive explanation of biology to a unique style of learning through graphic designs and quantitative parameters to realize how contributions from research and innovation have made the subjects modern, interdisciplinary and applied and laid the foundations of Zoology, Animal Sciences, Life Sciences, Molecular Biology and Biotechnology. These courses and their practical exercises will help the students to apply their knowledge in future course of their career development in higher education and research. In addition, they may get interested to look for engagements in industry and commercial activities employing Life Sciences, Molecular Biology and Biotechnology. They may also be interested in entrepreneurship and start some small business based on their interest and experience.

2.1 Nature and extent of the B.Sc. degree Programme in Zoology

B.Sc. Zoology course will help to understand the behaviour, structure and evolution of animals. Zoologists use a wide range of approaches to do this, from genetics to molecular and cellular biology, as well as physiological processes and anatomy, whole animals, populations, and their ecology. The scope of Zoology as a subject is very broad. The intention is to understand the subject of Zoology in the evolving biological paradigm in modern times; where, living beings need to be understood at the level of atomic interactions; and comparative systems of organisms need to be studied through the prism of integrated chemical, physical, mathematical and molecular entities to appreciate the inner working of different organisms at morphological, cellular, molecular, interactive and evolutionary levels. The key areas of study within the disciplinary/subject area of Zoology comprise: animal diversity, principles of ecology, comparative anatomy and developmental biology of vertebrates, physiology and biochemistry, genetics and evolutionary biology, animal biotechnology, applied zoology, behaviour, immunology, reproductive biology, and insect, vectors and diseases. B.Sc. degree programme in Zoology also deals with skill enhancement courses such as apiculture, aquarium fish keeping, medical diagnostics, sericulture etc. The depth and breadth of study of individual topics dealt with would vary with the nature of specific Zoology programmes. As a part of the efforts to enhance the interest and employability of graduates of Zoology programmes, the curricula for these programmes are expected to include learning experiences that offer opportunities for higher studies and research at reputed laboratories.

2.2 Aims of Bachelor's degree programme in Zoology

Zoology is the study of all animal life; from primitive microscopic malaria-causing protozoa to large advanced mammals, across all environmental spheres from red deer in mountain forests to dolphins in deep oceans, and from underground burrowing voles to golden eagles in the skies. Some of these animals are useful to us and we nurture them as pets or livestock; some are serious pests or disease-causing; and some are simply splendid and awe-inspiring. No matter what our relation with the animals is, we need to understand their behaviour, population dynamics, physiology and the way they interact with other species and their environments. It provides students with the knowledge and skill base that would enable them to undertake further studies in Zoology and related areas or in multidisciplinary areas that involve advanced or modern biology and help develop a range of generic skills that are relevant to wage employment, self-employment and entrepreneurship.

The modern era requires a classical zoologist with a modern approach to master many subjects of Zoology. There is a need for the students to compete with the globe, therefore, the main focus of this curriculum is to enable the student to be professionally competent and successful in a career. Having Zoology as backbone of the curriculum, this course, with the department centric electives will enhance the skills required to perform research in laboratory and experimental research. The students can choose to focus on a "whole animal" or a "bits of animals" approach. The "whole animal" pathway makes the students proficient in the identification and study of animals while the latter approach provides the skills required to pursue laboratory and experimental work such as disease research, DNA technologies, wildlife forensics etc. The curriculum can be modified to such extent that a student at B.Sc. level can be a specialist in immunology, ornithology, animal behaviour or entomology. For such specializations, the curriculum needs to focus on special skills to maximise the students' employment probability; for example few skills needed by industry may include the species-specific monitoring for key species, handling of dangerous/ poisonous/ wild animals and the use of Geographic Information Systems (GIS) for data collection.

3. Graduate Attributes in Zoology

- ***Disciplinary knowledge and skills:*** Capable of demonstrating (i) comprehensive knowledge and understanding of major concepts, theoretical principles and experimental findings in Zoology and its different subfields (animal diversity, principles of ecology, comparative anatomy and developmental biology of vertebrates, physiology and biochemistry, genetics and evolutionary biology, animal biotechnology, applied Zoology, aquatic biology, immunology, reproductive biology, and insect, vectors and diseases), and other related fields of study, including broader interdisciplinary subfields such as chemistry, physics and mathematics; (ii) ability to use modern instrumentation for advanced genomic and proteomic technology.
- ***Skilled communicator:*** Ability to impart complex technical knowledge relating to Zoology in a clear and concise manner in writing and oral skills.

- ***Critical thinker and problem solver:*** Ability to have critical thinking and efficient problem solving skills in the basic areas of Zoology (animal diversity, principles of ecology, comparative anatomy and developmental biology of vertebrates, physiology and biochemistry, genetics and evolutionary biology, animal biotechnology, applied Zoology, aquatic biology, immunology, reproductive biology, insect, vectors and diseases etc.).
- ***Sense of inquiry:*** Capability for asking relevant/appropriate questions relating to issues and problems in the field of Zoology, and planning, executing and reporting the results of an experiment or investigation.
- ***Team player/worker:*** Capable of working effectively in diverse teams in both classroom, laboratory and in industry and field-based situations.
- ***Skilled project manager:*** Capable of identifying/mobilizing appropriate resources required for a project, and manage a project to completion, while observing responsible and ethical scientific conduct; and safety and chemical hygiene regulations and practices.
- ***Digitally literate:*** Capable of using computers for Bioinformatics and computation and appropriate software for analysis of genomics and proteomics data, and employing modern bioinformatics search tools to locate, retrieve, and evaluate location and biological annotation genes of different species.
- ***Ethical awareness/reasoning:*** Capable of conducting their work with honesty and precision thus avoiding unethical behavior such as fabrication, falsification or misrepresentation of data or committing plagiarism, and appreciating environmental and sustainability issues. Research ethics committee expects them to declare any type of conflict of interest that may affect the research. Any plan to withhold information from researchers should be properly explained with justification in the application for ethical approval.
- ***Lifelong learners:*** Capable of self-paced and self-directed learning aimed at personal development and for improving knowledge/skill development and reskilling.

4. Qualification Descriptors for a Bachelor's Degree programme in Zoology

The qualification descriptors for a Bachelor's Degree programme in Zoology may include the following:

- Demonstrate (i) a fundamental/systematic or coherent understanding of the academic field of Zoology, its different learning areas and applications, and its linkages with related disciplinary areas/subjects; (ii) procedural knowledge that creates different types of professionals related to Zoology area of study, including research and development, teaching and government and public service; (iii) skills in areas related to specialization area relating the subfields and current developments in the academic field of Zoology.
- Use knowledge, understanding and skills required for identifying problems and issues relating to Zoology. A keen interest in research and the study of living organisms.
- Communicate the results of studies undertaken accurately in a range of different contexts using the main concepts, constructs and techniques of the subject(s);
- Meet one's own learning needs, drawing on a range of current research and development work and professional materials;
- Apply one's subject knowledge and transferable skills to new/unfamiliar contexts to identify and analyse problems and issues and solve complex problems with well-defined solutions.
- Demonstrate subject-related and transferable skills that are relevant to Zoology-related job trades and employment opportunities
- Good observation skills
- Able to work precisely
- A logical approach to problem-solving
- Good oral and written communication abilities
- Able to work independently or with team members

5. Learning Outcomes in Bachelor's Degree programme in Zoology

5.1 Knowledge and Understanding

- Demonstrate (i) in-depth knowledge and understanding about the fundamental concepts, principles and processes underlying the academic field of Zoology and its different subfields (animal diversity, principles of ecology, comparative anatomy and developmental biology of vertebrates, physiology and biochemistry, genetics and evolutionary biology, animal biotechnology, applied Zoology, aquatic biology, immunology, reproductive biology, and insect, vectors and diseases, apiculture, aquarium fish keeping, medical diagnostics, and sericulture) (ii) procedural knowledge that creates different types of professionals in the field of Zoology and related fields such as, apiculture, aquarium fish keeping, medical diagnostics, and sericulture, etc.(iii) skills related to specialization areas within Zoology as well as within subfields of Zoology, including broader interdisciplinary subfields (Chemistry, Physics and Mathematics).

- Over the years, Zoologists were able to find many differences within the same breed of an animal species. As a Zoology professional one can study extinct animals by specializing in Paleozoology, on the different types of birds in Ornitholog; opt for studying
- Herpetology and Arachnology, the branches dealing with the study of snakes and spiders, respectively or
- Appreciate the complexity of life processes, their molecular, cellular and physiological processes, their genetics, evolution and behaviour and their interrelationships with the environment.
- Study concepts, principles and theories related with animal behaviour and welfare.
- Understand and interpret data to reach a conclusion
- Design and conduct experiments to test a hypothesis.
- Understand scientific principles underlying animal health, management and welfare.
- Accept the legal restrictions & ethical considerations placed for animal welfare.
- Understand fundamental aspects of animal science relating to management of animals.

- Assess problems and identify constraints in management of livestock.

5.2 Subject Specific Intellectual and Practical Skills

The students will be able to

- Understand how organisms are classified and full and identified
- Demonstrate knowledge of basic zoological principles
- Use appropriate information with a critical understanding
- Learn basic laboratory and analytical skills
- Use effective methods for modifying animal behaviour
- Participate in animal management programmes in an effective manner
- Work safely and effectively in the field, in laboratories and in animal facilities
- Demonstrate competence in handling and statistical analysis of data gained from practical
- Learn communication and IT skills, including the collation and statistical analysis of data, citing & referencing work appropriately, communicating using a range of formats

In course learning outcomes, the student will attain subject knowledge in terms of individual course as well as holistically. The example related to core courses and their linkage with each other is stated below:

5.3 <u>Learning Outcomes of different types of courses for B.Sc. Zoology</u>

Core Courses (CC)

Programme Outcomes	**CC 1**	**CC 2**	**CC 3**	**CC 4**	**CC 5**	**CC 6**	**CC 7**	**CC 8**	**CC 9**	**CC 10**	**CC 11**	**CC 12**	**CC 13**	**CC 14**
Core competency	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Critical thinking	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Analytical reasoning	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Research-skills	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Teamwork	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

Discipline Specific Elective Courses (DSE)

Programme Outcomes	DSE 1	DSE 2	DSE 3	DSE 4	DSE 5	DSE 6	DSE 7	DSE 8	DSE 9	DSE 10	DSE 11
Additional Academic Knowledge	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Problem-solving	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Additional analytical skills	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Additional Research-skills	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

Generic Elective Courses (GEC)

Programme Outcomes	GEC 1	GEC 2	GEC 3	GEC 4	GEC 5	GEC 6	GEC 7	GEC 8	GEC 9	GEC 10	GEC 11	GEC 12	GEC 13
Additional Academic Knowledge	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Exposure beyond discipline	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Problem-solving	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Analytical reasoning	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

Ability Enhancement Course (AEC)

Programme Outcomes	AEC 1	AEC 2	AEC 3	AEC 4	AEC 5	AEC 6	AEC 7	AEC 8	AEC 9
Additional Academic Knowledge	☑	☑	☑	☑	☑	☑	☑	☑	☑
Psychological skills	☑	☑	☑	☑	☑	☑	☑	☑	☑
Problem-solving	☑	☑	☑	☑	☑	☑	☑	☑	☑

Skill Enhancement Course (SEC)

Programme Outcomes	SEC 1	SEC 2	SEC 3	SEC 4	SEC 5	SEC 6	SEC 7	SEC 8	SEC 9	SEC 10	SEC 11	SEC 12	SEC 13	SEC 14
Additional Knowledge enhancement	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Exposure beyond discipline	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Analytical reasoning	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Digital Literacy	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Moral and ethical awareness	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

The core courses would fortify the students with in-depth subject knowledge concurrently; the discipline specific electives will add additional knowledge about applied aspects of the program as well as its applicability in both academia and industry. Generic electives will introduce integration among various interdisciplinary courses. The skill enhancement courses would further add additional skills related to the subject as well as other than subject. In brief, the students graduated with this type of curriculum would be able to disseminate subject knowledge along with necessary skills to suffice their capabilities for academia, entrepreneurship and Industry.

For each syllabus, the course content has been divided into four units with a breakup of the topics to be covered to provide the students better understanding of the main theme represented in the title of each unit. Such type of design is to indicate the breadth of content to be taught thus ensuring more or less uniform coverage of information on a certain theme. The teacher has to take up the contents in such a manner by asking questions and answering them that the whole process appears to be an interesting narrative with topics falling in line rather than appearing as unrelated complex terms. Learning will be more enjoyable and imbibing if appropriate examples are cited from our daily lives.

6. Distribution of different courses with their credits for B.Sc. Zoology

6.1 Distribution of different types of courses with their credits for B.Sc. Zoology (Regular/ Pass Course)

Semester	**Core Courses (CC) (6x12=72)** Note: 14 CC are available. Choose 12 as compulsory. 6 credits (4T+ 2P) each	**Ability Enhancement Electives (AEC) (2x4=8)** Note: 9 AEC are available. Choose any 2; 4 credits each	**Skill Enhancement Electives (SEC) (4x4=16)** Note: 14 SEC are available. Choose any 4; 4 credits each	**Discipline Specific Electives (DSE) (3x6=18)** Note: 11 DSE are available. Choose any 3 6 credits (4T+ 2P) each	**Generic Elective (GEC) (3x6=18)** Note: 13 GEC are available. Choose any 3; 6 credits (4T+ 2P) each	**Credit hour load**
1.	CC-I CC-II	AEC			GEC	22
2.	CC-III CC-IV	AEC			GEC	22
3.	CC-V CC-VI		SEC		GEC	22
4.	CC-VII CC-VIII		SEC	DSE		22
5.	CC-IX CC-X		SEC	DSE		22
6.	CC-XI CC-XII		SEC	DSE		22
Credits	48(T)+24(P)=72	8(T)	16(T)	12(T)+6 (P)=18	12(T)+6(P)= 18	132
% Courses	54.6	6.0	12.2	13.6	13.6	100

6.2 Distribution of different types of courses with their credits for B.Sc. Zoology (Honours)

Semester	**Core Courses (CC) (6x14=84)** Note: 14 CC are available. All courses are compulsory. 6 credits (4T+ 2P) each	**Ability Enhancement Electives (AEC) (2x4=8)** Note: 9 AEC are available. Choose any 2; 4 credits each	**Skill Enhancement Electives (SEC) (2x4=8)** Note: 14 SEC are available. Choose any 2; 4 credits each	**Discipline Specific Electives (DSE) (4x6=24)** Note: 11 DSE are available. Choose any 4; 6 credits (4T+ 2P) each	**Generic Elective (GEC) (4x6=24)** Note: 13 GEC are available. Choose any 4; 6 credits (4T+ 2P) each	**Seminar/ Project/ group discussion (2x 10=20)** Choose any 2; 10 credits each	**Credit hour load**
1.	CC-I CC-II	AEC			GEC		22
2.	CC-III CC-IV	AEC			GEC		22
3.	CC-V CC-VI		SEC		GEC		22
4.	CC-VII CC-VIII		SEC		GEC		22
5.	CC-IX CC-X CC-XI			DSE DSE		SMR	30
6.	CC-XII CC-XIII CC-XIV			DSE DSE		SMR	30
Credits	56(T)+28(P)=84	8(T)	8(T)	16(T)+8 (P)=24	16(T)+8(P)= 24	20*	148
% Courses	56.80	5.40	5.40	16.20	16.20	13.5[1]*	100

*optional

7. Course Structure for Bachelor's Programme in Zoology with details

7.1 Core Courses

These courses provide an in depth understanding of relevant theories, concepts, and principles of zoology besides having an insight into the philosophy of the subject. The students are likely to have a strong foundation in Zoology.

S.N.	Name of course	Theory	Practical	Credits
1.	Systematics & Diversity of Life - Protists to Chordates	4	2	6
2.	Developmental Biology & Evolution	4	2	6
3.	Comparative Anatomy & Physiology of Non-chordates	4	2	6
4.	Cell Biology and Histology	4	2	6
5.	Comparative Anatomy & Physiology of Chordates	4	2	6
6.	Genetics	4	2	6
7.	Biochemistry	4	2	6
8.	Behaviour and Chronobiology	4	2	6
9.	Ecology	4	2	6
10.	Molecular Biology	4	2	6
11.	Biotechniques	4	2	6
12.	Microbiology, Parasitology & Immunology	4	2	6
13.	Biostatistics & Bioinformatics	4	2	6
14.	Applied Zoology	4	2	6

7.2 Discipline Specific Elective Courses

With the course content largely subject specific, the first aim of these courses is to engage all students in enriching, enjoyable and intellectually stimulating learning experiences. Methods are designed to support independent learning. The courses are likely to help students acquire subject-specific, cognitive and transferable skills to solve complex problems.

S.N.	Name of course	Theory	Practical	Credits
1.	Neuroscience	4	2	6
2.	Endocrinology	4	2	6
3.	Nanobiology	4	2	6

4.	Evolutionary Biology	4	2	6
5.	Mammalian Physiology	4	2	6
6.	Human Reproductive Biology	4	2	6
7.	Genetic Engineering and Biotechnology	4	2	6
8.	Agrochemicals and Pest management	4	2	6
9.	Wild Life Conservation and Management	4	2	6
10.	Aquatic Zoology	4	2	6
11.	Livestock Management and Animal Husbandry	4	2	6

7.3 Generic Elective Courses

These courses enable the students to apply knowledge and understanding to address not only the core issues but also the issues of general importance where the knowledge of Zoology can be an added advantage. The courses will facilitate the students to develop all-round knowledge and skills on the integrated subjects in life sciences.

S.N.	Name of course	Theory	Practical	Credits
1.	Exploring the Brain: Structure and Function	4	2	6
2.	Human Physiology	4	2	6
3.	Vectors, Diseases and Control	4	2	6
4.	Food, Nutrition and Health	4	2	6
5.	Global Climate change	4	2	6
6.	Environmental Microbiology	4	2	6
7.	Environmental Biotechnology	4	2	6
8.	Biodiversity Conservation and Sustainable Development	4	2	6
9.	Bioeconomics	4	2	6
10.	Systematics and Evolutionary Biology	4	2	6
11.	Global Environmental Issues	4	2	6
12.	Environmental Monitoring and Management	4	2	6

13	Basics of Systematics and Classification	4	2	6

7.4 Ability Enhancement Courses

These courses will mainly enhance the ability and personal skills of the students and help in personality development besides making them aware about the latest happenings or trends and facilitating effective communication with correct usage of technical language in order to present complex concepts and information. The students will learn to express in competitive and professional environments, orally and in writing in a clear and concise manner.

S.N.	Name of course	Theory	Practical	Credits
1.	Science Communication and Popularization	4		4
2.	Good Laboratory Practices	4		4
3.	Basic mathematics for Zoologists	4		4
4.	Research Methodology	4		4
5.	History of Indian Science	4		4
6.	Personality Development	4		4
7.	Human health and Sex Education	4		4
8.	Human Nutrition	4		4
9.	Intellectual Property Right			

7.5 Skill Enhancement Courses

These courses will encourage and enhance the investigative and analytical skills of students resulting in their ability to formulate problems clearly, identify key issues and reach the solution with logical arguments. The classroom sessions are aimed to provide industry-standard skills and can be helpful in fetching jobs.

S.N.	Name of course	Theory	Practical	Credits
1.	Reproductive Technologies	4		4
2.	Public Health and Hygiene	4		4
3.	Dairy Production and Technology	4		4
4.	Computer Applications	4		4
5.	Biofertilizers	4		4
6.	Environmental Impact Analysis	4		4

7.	Insect pest, vector biology and management	4		4
8.	Preventive medicine	4		4
9.	Ornamental freshwater fish production	4		4
10.	Aquaculture	4		4
11.	Toxicology	4		4
12.	Beekeeping	4		4
13.	Sericulture	4		4
14.	Ecotourism	4		4

The experiments involving animals will be performed through permanent slides/photographs/ video recording/ as per UGC guidelines.

8. Assessment and Evaluation

8.1 Assessment methods

Students' performance in core, discipline electives, generic electives and skill enhancement courses are to be assessed in various ways *viz.*,

- The oral and written scheduled or surprise tests,
- Problem-solving exercises,
- Closed-book and open-book tests,
- Practical skills and laboratory reports,
- Individual and group project reports,
- Seminar presentations,
- Group discussions
- *Viva voce* examinations.
- The computerized learning, literature surveys and evaluations, peers and self-assessment can be the additional methods used.
- Regular reading habits in the students need to be inculcated through continuous monitoring and observation about weaker aspect of the students.

8.2 List of Topics Suggested for Seminar and Group Discussion

1. Origin of life
2. Molecular systematics vs traditional taxonomy
3. Molecular system of classification
4. Living fossils
5. Animal connecting links
6. Reliability of taxonomic characters
7. Scope of evo-devo (Evolutionary developmental biology)
8. Mass extinction phenomenon
9. Pleuripotency and its relevance
10. Latest trends in developmental biology
11. Evolution of major animal lineages
12. Relevance of Palaentology in current scenario
13. Parthenogenesis in animals
14. Polymorphism
15. Parasitic adaptations
16. Metamorphosis
17. Freshwater sponges
18. Molluscs of industrial value
19. Coral reefs and their role in ecosystem generation
20. Biochemical pathways, their evolutionary background and regulation
21. Water regulation in marine animals
22. Were dinosauers warm blooded?
23. Evolution of terrestrial animals
24. Blood groups and their importance
25. Role of DNA sequencing in evolutionary history.
26. Genetic control of sex determination.
27. Bone marrow transplant
28. Recent advances in tissue culture and engineering.
29. Somatic hybridization
30. Neurodegenerative disorders
31. Popular cell lines and their importance
32. Apoptosis

33. Mutations and cancer
34. Epithelial tissue and its importance
35. Genome modification/ editing
36. Recent advances in gene cloning
37. Epigenetic disorders in humans
38. Diseases due to chromosomal anomalies
39. Stem cell technology
40. Genetic counseling
41. RNA interference
42. DNA barcoding
43. Stem cells & IPS cells
44. Current trends in DNA sequencing
45. DNA markers and Genetic diversity
46. Comparative genomics in understanding of gene function
47. Biodiversity and climate change
48. Biotechnology: Past, present and Future.
49. Molecular Taxonomy, New Classification systems
50. Tree of Life.
51. Marine zooplanktons and their ecological importance including oxygen evolution
52. Bioprospecting and Biopiracy
53. Molecular systematics vs. traditional taxonomy
54. Biochemical Pathways and their evolutionary background, Regulation
55. Biodiversity Hotspots.
56. Biotechnology; Past present and Future
57. Climate change: threat to food security
58. Stratospheric Ozone depletion and marine productivity
59. Good ozone vs. bad ozone
60. Air pollution and climate change
61. Biodiversity under climate changing scenario
62. Preparing healthy/ fit animal stock for tomorrow ; Conventional Breeding
63. Hybrids or transgenic animals
64. Vital body enzymes
65. Hormonal disorders

66. The process of Transcription
67. Advances in DNA hybridization
68. Essential and non essential amino acids
69. Important body lipids
70. Parental care in animals
71. Learning in birds
72. Instinctive behaviour invertebrates
73. Social behaviour in primates
74. Application of animal behaviour studies
75. Behaviour in captivity
76. Circadian rhythm
77. Environmental ethics
78. Biodiversity hotspots
79. Biodiversity mapping
80. Population explosion
81. Ecological indices
82. Niche segregation
83. Carrying capacity
84. Eukaryotic genome
85. Regulation of gene expression
86. RNA editing and splicing
87. DNA damage and repair
88. Central dogma of molecular biology
89. Molecular cloning
90. Monoclonal and polyclonal antibodies production techniques
91. Immunological techniques in disease diagnosis
92. Basic principles of light microscopy
93. Using SEM and TEM
94. Principles of Florescence and confocal microscopes
95. Applications of calorimetry and spectrophotometry
96. Techniques involving separation of biomolecules.
97. Diseases caused by viruses
98. Common bacterial diseases

99. Autoimmune diseases
100. Hybridoma technology and its applications
101. Zoonotic diseases
102. Helminth infections in humans
103. Concept of Immunity
104. Graphical representation of biological results
105. Statistical methods of hypothesis testing
106. Information technology in data acquisition and retrieval
107. Database management
108. Use of bioinformatics in biological research
109. Basics of information technology
110. Fish culture
111. Dairy management
112. Cattle diseases and their management
113. Apiculture and Sericulture
114. Pearl culture industry
115. Vermiculture
116. Prawn culture, a good source of revenue generation
117. In vitro fertilization techniques
118. Phenoplasticity and its relevance

8.3 Suggested List of Supplementary Web Resources for Laboratory Exercises

1. Anatomy of Frog: Pro Dissector (CD)- www.prodissector.com
2. Physiology of Frog: Physio Ex 4.0 (CD)- www.physioex.com
3. Anatomy of Chordates: The Vertebrate Dissection Guide Series (CD)–Learning Development Centre, University of Portsmouth
4. Anatomy of earthworm: The dissection works (CD); Source – www.scienclass.com; www.neosci.com
5. Anatomy of shark: Shark dissection and anatomy (video)- www.neosci.com
6. Cockroach dissection- www.ento.vt.edu
7. Mammalian Physiology– www.biopac.com

8.4 Guidelines for Individual/ Team Projects and Field Reports

The aim of the individual/ team project/s is to develop an aptitude for research in Zoology and to inculcate proficiency to identify appropriate research topic and presentation.

The topics of biological interest and significance can be selected for the project. Project is to be done by a group not exceeding 5 students. The project report should be submitted on typed A4 paper, 12 Font, 1.5 Space in spirally bound form and duly attested by the supervising teacher and the Head of the Department on the day of practical examination before a board of two Examiners for End Semester. The viva-voce based on the project is conducted individually. Project topic once chosen shall not be repeated by any later batches of students.
The project report may have the following sections:
1. Preliminary (Title page, declaration, certificate of the supervising teacher, content etc.)
2. Introduction with relevant literature review and objective
3. Materials and Methods
4. Result
5. Discussion
6. Conclusion / Summary
7. References.

Field Study/ Study tour
Students have to visit one research institute and one wild life sanctuary / museum / zoo. Scientifically prepared hand-written study tour report along with photographs of candidate at the places of visit must be submitted by each student for End Semester on the day of the examination of project.

B.Sc. Zoology

Core Courses (CC)

Semester	Core course	Course Title	Credit
I	**CC-1**	**Systematics and Diversity of Life-Protists to Chordates**	Theory:04 Practical: 02 Total: 06

About the course

The course is a walk for the Bachelor's entrant through the amazing diversity of living forms from simple to complex one. It enlightens how each group of organisms arose and how did they establish themselves in the environment with their special characteristics. It also deals with the differences and similarities between organisms on the basis of their morphology and anatomy which led to their grouping into taxa and clades.

Learning outcomes

After successfully completing this course, the students will be able to:

- Develop understanding on the diversity of life with regard to protists, non chordates and chordates.
- Group animals on the basis of their morphological characteristics/ structures.
- Develop critical understanding how animals changed from a primitive cell to a collection of simple cells to form a complex body plan.
- Examine the diversity and evolutionary history of a taxon through the construction of a basic phylogenetic/ cladistics tree.
- Understand how morphological change due to change in environment helps drive evolution over a long period of time.

- The project assignment will also give them a flavour of research to find the process involved in studying biodiversity and taxonomy besides improving their writing skills. It will further enable the students to think and interpret individually due to different animal species chosen.

Theory

UNIT I: Origin of Life on Earth, Products of evolutionary process **13 Lectures**

Origin of life on Earth: Arrival of simple form from primordial chemicals. Multicellularity: from simple collections of poorly differentiated cells to complex body plans. Biological diversity. Systematics and taxonomy. Species concept, clades. Nomenclature and utility of scientific names. Classification: morphological and evolutionary (molecular). Relationship of taxa: phylogenetics and cladistics with special reference to paraphyly, monophyly, apomorphy, plesiomorphy and phenoplasticity

UNIT II: Diversity in Protists and acoelomate Metazoa **13 Lectures**

Structure and diversity in Protists. Origin of Metazoans: Diploblastic and triploblastic organization; symmetries; body cavities; protostomes and deuterostomes. Special features and structural diversity in sponges. Cnidarians: Special features; transition of third germ layer; polymorphism and division of labour; coral reef forming Cnidarians. The Bilateria: Basic characteristics. The acoelomates: Basic organization and adaptive radiations in flatworms.

UNIT III: Diversity in pseudocoelomate and coelomate Non chordates **13 Lectures**

The Ecdysozoa: characteristics of the representative taxa. Pseudo coelomates; Basic organization and adaptive radiations in roundworms. The coelomates: Basic organization and adaptive radiations in Arthropods- Ancestors/ fossil arthropods. Adaptive radiations in Crustaceans, Myriapods, Chelicerates, Insects, etc. Basic organization and diversity in Annelids. Basic organization and diversity in Molluscs. Disruption of bilateral symmetry and its significance. Basic organization of Echinoderms; their affinity to Chordates.

UNIT IV: Diversity in Protochordates and Chordates **13 Lectures**

Chordates – Primitive Chordates and their affinities. Hemichordates, Urochordates and Cephalochordates. Advent of vertebrates: Cyclostomes, their evolutionary status and affinities. Basic organization and diversity of fishes, their evolutionary transitions. From

Water to Land invasion - Early Tetrapodes. Amphibians diversity and adaptability to dual mode of life. Amniotes: the amniotic egg, adaptive radiations in reptiles; the avian ancestors. Birds: Adaptation from terrestrial to aerial mode of life. Origin of Mammals- Special features of Monotremes and Marsupials. Characteristics of other mammalian groups with special reference to primates

Recommended readings

- Barnes, R. S. K.; Calow, P.; Olive, P. J. W.; Golding, D. W.; Spicer, J. I. (2002) The Invertebrates: a Synthesis, Blackwell Publishing.
- Hickman, C.; Roberts, L.S.; Keen, S.L.; Larson, A. and Eisenhour, D. (2018) Animal Diversity, McGraw-Hill.
- Holland, P. (2011) The Animal Kingdom: A Very Short Introduction, Oxford University Press.
- Kardong, K.V. (2006) Vertebrates: Comparative Anatomy, Function, Evolution (4th edition), McGraw- Hill.
- Barrington, E.J.W. (1979) Invertebrate Structure and Functions. II Edition. E.L.B.S. and Nelson.
- Boradale, L.A. and Potts, E.A. (1961) Invertebrates: A Manual for the use of Students. Asia Publishing Home.
- Bushbaum, R. (1964) Animals without Backbones. University of Chicago Press.

Practical

1. Study of animals through slides and museum specimens in the laboratory with details on their classification, biogeography and diagnostic features (record book).
2. Study of animals in nature during a survey of a National Park or Forest area.
3. Collection of five species (preferably invertebrates, insects) belonging to a clade. A project work on their generic identification, description and illustration with a note on their locality. Also the assessment of their relationship by constructing a cladogram using characters and character states.
4. Comparison of two species of birds belonging to same genus (Interspecific difference).
5. Comparison and weighting of characters of two birds belonging to same family but dissimilar genera.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28)

Semester	Core course	Course Title	Credit
I	**CC-2**	**Developmental Biology & Evolution**	Theory:04 Practical: 02 Total: 06

About the course

The course explains the sequence of events starting with a single cell to the production of a very complex organism. The course not only describes how embryos develop (embryology), but also highlights how the processes of development are brought about by changing individual cells into specialized cells with specific functions (the cellular level), and how genes within the genome of the organism drive and guide these changes (the molecular level). It also deals with a comparative account of development in some select groups of animals.

Learning outcomes

After successfully completing the course, the students will be able to

- Develop critical understanding how a single-celled fertilized egg becomes an embryo and then a fully formed adult by going through three important processes of cell division, cell differentiation and morphogenesis.

- Understand how developmental processes and gene functions within a particular tissue or organism can provide insight into functions of other tissues and organisms.
- Realize that very similar mechanisms are used in very diverse organisms; and development is controlled through molecular changes resulting in variation in the expression and function of gene networks.
- Understand how the field of developmental biology has changed since the beginning of the 19^{th} century with different phases of developmental research predominating at different times.

- Examine the evolutionary history of the taxa based on developmental affinities.
- Understand the relevance of developmental biology in medicine or its role in development of diseases.

Theory

UNIT I: How does reproduction start, commence and modify in living system?
13 Lectures

Reproduction: a basis of species sustenance. Asexual and sexual reproduction and their relevance in corresponding environments. How are germ cells "special"? Gamete formation, types, their diversity and competence, external and internal fertilization; causes of Infertility. Structural and biochemical changes in gametes during and after fertilization, block to polyspermy. Establishment of the major embryonic axes, polarity, morphogen gradients and their interpretation. Fate maps, their relevance. *In vitro* fertilization; Amniocentesis; Artificial insemination (AI); Gamete intra-fallopian transfer (GIFT). Intra-cytoplasmic sperm injection (ICSI); Test tube baby.

UNIT II: How does development affect organization of phenotypes and their variation?
12 Lectures

Developmental commitment. Mosaic and regulative development. Direct and indirect development. Cleavage: types and patterns. Body plan and symmetries. Germ layer differentiation. Tubulation. Morphogenesis: Epiboly, emboly/ invagination, involution and ingression. Cell-cell interactions (cell signaling, cell adhesion etc.) during tissue organization, lateral inhibition, induction, and recruitment. Organogenesis: formation of gut, heart, kidney and muscles. Concept of competence, determination and differentiation and growth, molecular mechanism involved. Pleuropotency. Stem cell biology and tissue repair

UNIT III: Tracing the evolutionary biology of development **12 Lectures**

Role of extra embryonic membranes in development, Placenta: types, structure and functions. Metamorphosis in insect and frog. Regeneration: epimorphosis, morphollaxis and compensatory regeneration. Development, ageing and apoptosis. Developmental mechanisms of evolutionary change (Evo-devo). Ecological Developmental Biology. Developmental biology in understanding of disorders. Teratogenesis; wound healing, birth defects, developmental brain disorders. Neurodegeneration. Endocrine Disruptors & Cancer.

UNIT IV: Understanding evolution through natural selection, adaptation and optimal models tradeoffs **15 Lectures**

Early life on Earth and its indirect evidences, direct evidence of early life; great oxygenation and its relationship with life. Evolution and radiation of metazoans, major evolutionary transitions, Mass extinctions, Anthropocene and its uniqueness. Evidences of evolution: Hardy-Weinberg Equilibrium, Selection, Migration. Nonrandom mating, Cost/ benefit of sex, Sexual conflict, Evolution in asexual systems Life-history adaptations, Trade-offs, Number and size of offspring; Parent-offspring conflict. Genetic drift, Neutral evolution; Theories of evolution. Linkage disequilibrium; Epistasis. Heritability; Breeding value. Sources of variation: mutation, recombination, epigenetic variation. Evolution of mutation rates. Phenotypic plasticity, Genome evolution: Mobile genetic elements; gene duplication. Evolution and Health: Evolution of antibiotic Resistance, Virulence, Evolutionary medicine.

Recommended readings

1. Gerhart, J. *et al*. (1997) Cells, Embryos and Evolution. Blackwell Science
2. Gilbert, S.F. (2010) Developmental Biology (9th edition). Sinauer
3. Wolpert, L. (2007) Principles of Developmental Biology (3rd edition). Oxford University Press
4. Campbell, N. and Reece, J. (2014) Biology (10th edition). Benjamin Cummings
5. Ridley, M. (2004). *Evolution*. III Edition. Blackwell Publishing.
6. Barton, N. H., Briggs, D. E. G., Eisen, J. A., Goldstein, D. B. and Patel, N. H. (2007). *Evolution*. Cold Spring, Harbour Laboratory Press.
7. Hall, B. K. and Hallgrimsson, B. (2008). *Evolution*. IV Edition. Jones and Bartlett Publishers

Practical

1. Types of eggs based on quantity and distribution of yolk: sea urchin, insect, frog, Chick.

2. Comparative study of cleavage patterns in Frog and Amphioxus models.
3. How do cells move, change shape and size during morphogenetic movement of Blastulation, Gastrulation in Frog, Amphioxus, Chick?
4. Study of development of chick embryo through incubated chick eggs up to 96 h.
5. Extra embryonic membranes of chick through permanent slides.
6. Some videos to develop understanding on the process of development.
7. Study of adaptive radiations in feet of birds and mouth parts of insects.
8. Understanding embryological evidence of evolution (through charts and videos).
9. Study of types of fossils.
10. Analogy and homology (wings of birds and insects, forelimbs of bat and rabbit).
11. Serial homology in appendages of *Palaemon.*

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
II	**CC-3**	**Comparative Anatomy and Physiology of Non-chordates**	Theory:04 Practical: 02 Total: 06

About the course

The course makes a detailed comparison of the anatomy of the different taxa of non chordates. It also highlights how in the taxonomic hierarchy, there is an increase in the complexity of structure and function. The course thus gives an overview of the intricate life processes and adaptive radiations in non chordates.

Learning outcomes

After successfully completing this course, the students will be able to

- Develop an understanding of the characters used to classify besides being able to differentiate the organisms belonging to different taxa.
- Acquire knowledge of the coordinated functioning of complex human body machine.
- Have hands on experience of materials demonstrating the diversity of protists and non-chordates.
- Understand the relative position of individual organs and associated structures through dissection of the invertebrate representatives.
- Realize that very similar physiological mechanisms are used in very diverse organisms.
- Get a flavor of research by working on project besides improving their writing skills. It will further enable the students to think and interpret individually.
- Undertake research in any aspect of animal physiology in future.

Theory

UNIT I: Diversity of Tegument and Digestive system 13 Lectures

Basic affinities and differences between prokaryotes and eukaryotes; protists and the non-chordate animals. Symmetry, Coelom development and diversity. Cell membrane in protists and its derivatives. Tegument in non-chordates and its derivatives. Nutrition and feeding modes in protists. Digestive system & feeding mechanism in non-chordates): Process of digestion from food vacuoles to complex digestive organs.

UNIT II: Diversity of Locomotory, Respiratory, Circulatory and Excretory systems 13 Lectures

Locomotion and diversity of locomotory organs in protists and non-chordates, muscle and locomotion, Structure and diversity of skeletal elements in protists and non-chordates. Respiration: diversity of respiratory organs, modes of respiration. Respiratory pigments and oxygen consumption rates of different organisms. Circulation and the diversity of circulatory system. Excretion (protists): endocytosis, exocytosis; Excretion and diversity of excretory organs in non chordates.

UNIT III: Diversity of Nervous and Reproductive systems 13 Lectures

Nervous system with special reference to diversity in brain and nerve chord. Neuroendocrine systems, pheromones. Sense organs: Mechanoreceptors and their diversity in different taxa. Sense organs: photoreceptors, chemoreceptors, thigmoreceptors, rheoreceptors and proprioceptors in different taxa. olfaction and sound perception in insects, etc. Diversity of the reproductive organs and accessory sex organs; modes of reproduction- asexual and sexual reproduction. Metamorphosis. Diversity of larval forms in non-chordates

UNIT IV: Evolution and characteristics of important Non Chordate taxa 13 Lectures

Organization and affinities in fossils (such as trilobites). Affinities of living fossils, *Limulus* and *Peripatus.* Polymorphism and colony formation. Parasitc adaptations and life cycle patterns in parasites belonging to different taxa. The parasites listed by World Health Organization under preventive programmes. Structure and diversity of the pest organisms. Invertebrate model organisms and their importance. Taxa with special characteristics: Types of canal systems in sponges and their significance. Torsion and detorsion in Mollusca. Components of water vascular system in echinoderms.

Recommended readings

1. Barrington, E J W. (1967) Invertebrate structure and function, Nelson, London.
2. Barnes, R. D. (1968) Invertebrate Zoology, 2nd Ed. Saunders, Philadelphia.
3. Hyman, L H. (1940-67). The Invertebrates, Vol. I-VI. McGraw-Hill, New York.
4. Barnes, R.S.K., Calow, P., Olive, P.J.W., Golding, D.W. and Spicer, J.I. (2002) The Invertebrates: A New Synthesis. III Edition. Blackwell Science.
5. Boradale, L.A. and Potts, E.A. (1961) Invertebrates: A Manual for the use of Students. Asia Publishing Home.
6. Marshall, A.J and Williams, W.D. (1995) Text book of Zoology-Invertebrates. VII Ed., Vol. I, A.L.T.B.S. Publishers.
7. http://abacus.bates.edu/acad/depts/biobook/AnimPhyl.pdf

Practical

1. Study of models, permanent slides and museum specimens representing different protists and non-chordate taxa.
2. Some additional slides/specimens of
   Protozoans of agricultural importance.
   Coral-reef forming Cnidarians
   Plant parasitic nematodes
   Nematodes used as models in experimental biological research
3. Dissection of *Pheretima* to expose circumpharyngeal ganglia
4. Dissection of *Periplaneta* to expose the digestive system and salivary glands
5. Dissection of *Palaemon* to expose appendages and statocyst
6. Dissection of *Pila*
7. Study of larval forms: *Ephyra*, *Planula*, *Trochophore*, *Pluteus*, *Velliger*, **Zoea**, Metazoea, Bipinnaria
8. Some videos to develop understanding on the animals of different taxa.

9. Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
II	**CC-4**	**Cell Biology and Histology**	Theory:04 Practical: 02 Total: 06

About the course

The course provides a detailed insight into basic concepts of cellular structure and function. It also gives an account of the complex regulatory mechanisms that control cell function.

Learning outcomes

After successfully completing this course, the students will be able to

- Understand the functioning of nucleus and extra nuclear organelles and understand the intricate cellular mechanisms involved.
- Acquire the detailed knowledge of different pathways related to cell signaling and apoptosis thus enabling them to understand the anomalies in cancer.
- Develop an understanding how cells work in healthy and diseased states and to give a 'health forecast' by analyzing the genetic database and cell information.
- Get new avenues of joining research in areas such as genetic engineering of cells, cloning, vaccines development, human fertility programme, organ transplant, etc.
- Understand how tissues are produced from cells in a normal course and about any malfunctioning which may lead to benign or malignant tumor.

Theory

UNIT-I: The structure and organelles of prokaryotic and eukaryotic cells. 13 Lectures

Cell biology, its scope in modern perspective. Cell theory and its modern version and interpretation. General structure of prokaryotes, bacteria, archaea and eukaryotes. Extra nuclear cell organelles: Ultrastructure and functions of endoplasmic reticulum, ribosome, Golgi apparatus, lysosome, peroxisomes. Mitochondria: Origin, structure, composition, genome organization and function. Cytoskeleton: composition and functions; microtubules and microfilaments. MT *vs* Actin - their organization, association with membrane. Nucleus: size, shape, structure and functions of interphase nucleus. Ultrastructure of nuclear membrane and pore complex. Nucleolus: general organization, chemical composition and functions, nuclear sap/ nuclear matrix, nucleo-cytoplasmic interactions.

UNIT-II: Cell membrane and transport mechanism 12 Lectures

Cell membrane organization: cell membrane: origin, structure, composition, models and function. Fluid mosaic model. Lipid Composition, inner and outer leaflets. Structure and functions of membrane proteins: Integral, peripheral and lipid-anchored membrane proteins. Junctional complexes, membrane receptor modifications: microvilli, desmosomes and plasmodesmata. Receptor mobility and clustering in the lipid bilayer. Cell receptor function - cellular trafficking. Transport across membrane: diffusion and osmosis. Active and passive transport, endocytosis and exocytosis

UNIT-III: Cell cycle, cell signaling and cell culturing 14 Lectures

Cell cycle, cell division- mitosis and meiosis. Cell division check points and their regulation. Role of growth factors. Mutations in the genes that regulate cell cycle and division and their role in causing cancer. Programmed cell death (Apoptosis). Cell regulation and Cell signaling: Signaling molecules and their receptors. Functions of cell surface receptors. Regulation of signaling pathways. Cell culture: Types of cell culture- monolayer and suspension culture. Types of culture media. Sterilization methods for culture wares and culture media. Maintenance of a cell line and storage of cells. Subcellular fractionation by differential centrifugation. Somatic cell hybridization. Basic characteristics of tissue culture media. Tissue culture and engineering.

UNIT-IV: Structural and functional significance of animal tissues 13 Lectures

Introduction to tissues. Epithelial tissue: types, structure and characteristics. surface modifications. Basement membrane: structure and characteristics. Cell junctions. Exocrine and endocrine glands: types and structure. Connective tissue cells. Structure and function of loose, dense and adipose tissue. Cartilage and bone: classification, and fine structure. Blood: plasma, blood cells, lymph– their structural and functional. Bone marrow and haemopoesis. Structure and function of spleen. Muscular tissue: ultrastructure of smooth, skeletal and cardiac muscles. Muscle-tendon attachment. Structure and classification of neurons. Types of supporting (glial) cells and their function. Myelin sheath and its formation. Types of sensory nerve endings. Degeneration and regeneration of neurons. Membranes of the brain and spinal cord.

Recommended readings

1. Karp, G. (2010) Cell and Molecular Biology: Concepts and Experiments (6th edition) John Wiley & Sons. Inc.

2. De Robertis, E.D.P. and De Robertis, E.M.F. (2006) Cell and Molecular Biology (8th edition) Lippincott Williams and Wilkins, Philadelphia.

3. Cooper, G.M. and Hausman, R.E. (2009) The Cell: A Molecular Approach. (5th edition) ASM Press & Sunderland, Washington, D.C.; Sinauer Associates, MA.

4. Becker, W.M.; Kleinsmith, L.J.; Hardin. J. and Bertoni, G. P. (2009) The World of the Cell. (7th edition) Pearson Benjamin Cummings Publishing, San Francisco.

Practical

1. Study of prokaryotic and eukaryotic cell types with the help of chart, slide and video.
2. Separation and isolation of cells by sedimentation velocity in unit gravity.
3. Disruption of cells, isolation and identification of subcellular components, isolation of nuclei.
4. Isolation of mitochondria by differential centrifugation and identification of succinic dehydrogenase in the mitochondrial pellet.
5. Chromosome segregation in mitosis and meiosis.
6. Preparation of chromosome squashes from grasshopper/cockroach testes for the observation of stages of meiosis.
7. Study of types of tissue through permanent slides: epithelial, connective, muscular, nervous etc.
8. Study of histology of tissues by preparing permanent stained slides through microtomy.
9. Isolation and estimation of DNA.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
III	**CC-5**	**Comparative Anatomy and Physiology of Chordates**	Theory:04 Practical: 02 Total: 06

About the course

The course offers insight into the physiology of chordates while giving an account of their anatomy. This course also explores vertebrate morphology with the aims of understanding major events in the history of vertebrate evolution and integrating the morphology of vertebrates with their ecology, behaviour and physiological adaptation in diverse habitats. Thermal relations encountered in endo- and ectothermic animals will be explained. Selective pressures that shape to different physiological phenotypes will also be addressed in the course.

Learning outcomes

After successfully completing this course, the students will be able to:

- Develop an understanding of the evolution of vertebrates thus integrating structure, function and development.
- Have an overview of the evolutionary concepts including homology and homoplasy, and detailed discussions of major organ systems.
- Understand how cells, tissues, and organisms function at different levels. The course content also provides the basis of understanding their abnormal function in animal and human diseases and new methods for treating those diseases.
- Develop an understanding of the related disciplines, such as cell biology, neurophysiology, pharmacology, biochemistry etc.
- Get a flavor of research besides improving their writing skills and making them well versed with the current trends. It will further enable the students to think and interpret individually due to different aspects chosen.
    - Undertake research in any aspect of animal physiology in future.

Theory

UNIT- I: Structure and function of integument, skeletal and muscular systems

11 Lectures

Structure of integument from fishes to mammals with an account on epidermal and dermal derivatives and their functional significance. Anatomy and physiology of axial and appendicular skeleton. Comparative anatomy of pelvic and pectoral girdles from fishes (cartilaginous and bony) to mammals. Types of muscles, physical properties and ultrastructural organization of skeletal muscle fibres, muscle contraction.

UNIT-II: Structure and function of digestive, circulatory and endocrine systems

13 Lectures

Comparative anatomy of jaw suspension, oral cavity, teeth (dentition mammals). Structure and diversity of alimentary canal and digestive glands in chordates. Biological significance of nutrients- carbohydrates, proteins, fats, vitamins and minerals. Physiology of digestion with special reference to enzymes involved. Evolution of aortic arches and their significance. Visceral arches and their functional significance in vertebrates. Structure and evolution of heart in vertebrates. Functional anatomy of heart, cardiac cycle, cardiac output, Integration of cardiovascular function, electrocardiogram. Composition of blood, blood groups, Mechanism of blood coagulation. Types and functional significance of endocrine glands and hormones.

UNIT-III: Structure and function of respiratory and excretory systems

14 Lectures

Aquatic and terrestrial respiration; transition from water to air breathing. Breathing and gas exchange, gas transport, Hb and O_2 dissociation, BMR. Comparative anatomy and functional significance of lungs in amphibians, reptiles, birds and mammals. Types and development of kidneys and their ducts in anamniotes and amniotes. Nephron- structure, types and their function. Physiology of excretion in vertebrates; urine formation, counter current mechanism, Role of ADH and RAAS in excretion. Mechanisms of osmoregulation in fresh water and marine organisms, stenohalinity and euryhalinity.

UNIT- IV: Structure and function of nervous and reproductive systems

14 Lectures

Introduction to central and peripheral nervous systems. Structural and functional evolution of brain and spinal cord in various classes of chordates. Peripheral nervous system- functional significance of somatic and autonomic nervous systems. Structure and functions of neuron, ionic basis of resting and action potentials, nerve impulse and its transmission, synapse and synaptic transmission, Reflex action. Types of sense organs- vision, hearing, taste, smell and touch in chordates. Mechanism of thermoregulation in homeotherms and poikilotherms. Comparative details of testes and ovaries from fishes to mammals; modes of reproduction; estrous and menstrual cycle, implantation, gestation, parturition, lactation and birth control.

Recommended readings

1. Weichert, C.K. (1970) Anatomy of Chordates (4th edition).
2. Jordan, E. L. and Verma, P. S. (2013) Chordate Zoology (14th edition).
3. Saxena, R. K. and Saxena, S. (2015) Comparative Anatomy of Vertebrates (2nd edition).
4. Vander, A.; Sherman, J. and Luciano, D. (2003) Human Physiology (9th edition).
5. Randall, D. *et al*. (2002) Eckert Animal Physiology (5th edition) Freeman.
6. Hill, R.W. *et al.* (2008) Animal Physiology (3rd edition) Sinaur Associates.
7. Guyton, A.C. *et al*. (2008) Textbook of Medical Physiology (12th edition) W.B. Saunders Co.
8. Withers, P.C. *et al.* (1992) Comparative Animal Physiology (1st edition) Brooks Cole.

Practical

1. Temporary mount of external scales in fishes (cycloid, placoid, ganoid, ctenoid).
2. Comparative study of brain with the help of models and charts.
3. Comparative study of urinogenital system with the help of models and charts.
4. Comparative study of heart with the help of models and charts.
5. Mount of weberian ossicles of fish.
6. Study of axial and appendicular skeleton of vertebrates.
7. Qualitative analysis of nutrients: Carbohydrate, Proteins, Lipids.
8. Estimation of haemoglobin.

9. Counting of different types of blood cells using haemocytometer.
10. Study of action of salivary amylase.
11. Rate of oxygen uptake in fish.
12. Effect of temperature on opercular movement of fish.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
III	**CC-6**	**Genetics**	Theory:04 Practical: 02 Total: 06

About the course

The course is designed to revise basic concepts of Genetics and then move on to advanced concepts. Some key aspects include the mechanism of inheritance, gene structure and function, sex chromosomal and autosomal anomalies, aspects of human genetics, etc. will be covered. A strong emphasis will be laid on the modern tools and techniques used in genetics.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand how DNA encodes genetic information and the function of mRNA and tRNA
- Apply the principles of Mendelian inheritance.
- Understand the cause and effect of alterations in chromosome number and structure.
- Relate the conventional and molecular methods for gene manipulation in other biological systems.
- Discuss and analyse the epigenetic modifications and imprinting and its role in diseases.
- Get new avenues of joining research in related areas such as genetic engineering of cells, cloning, genetic disorders, human fertility programme, genotoxicity, etc

Theory

UNIT I: Concept of Genes and Genomics **13 Lectures**

Genetics: scope and importance. Elements of heredity and variation: Classical and Modern concept of Gene (Cistron, muton, recon), Alleles etc. Mendel’s laws of inheritance, Chromosomal basis of inheritance and its applications. Exceptions to Mendelian Inheritance: Incomplete dominance, Codominance, Multiple allelism, Lethal alleles, Pleiotropy, Epistasis

- Recessive, Double recessive and double dominant. Genomic imprinting, Penetrance and expressivity, Phenocopy, Polygenic inheritance. Mendelian traits in man.

UNIT II: The recombination and interaction of Genes 13 Lectures

Linkage and crossing over, cytological basis of crossing over. Organelle inheritance (Mitochondrial) Extra-nuclear inheritance, Maternal Inheritance, Sex Chromosomes and sex-linkage: XX/XO, XX/XY, ZZ/ZW and haploidy/diploidy types, Gene dosage Compensation, Epigenetics. Structural and numerical alterations of chromosomes, meiotic consequences in structural heterozygotes. Autosomal dominant and autosomal recessive, X-linked dominant, and X-linked recessive. Haplodiploidy. Genic balance theory, intersex, gynandromorphs. Hormonal influence on sex determination-Freemartin and sex reversal. Role of environmental factors- *Bonellia* and Crocodile.

UNIT III: Regulation of Gene expression, regulation and mapping 13 Lectures

Gene Expressions and regulation**:** One gene-one enzyme hypothesis /one polypeptide hypothesis. Concept of operon of bacteria and bacteriophages. Bacterial transposons. Vertical and horizontal gene transfer. Transformation, transfection and transduction. Genetic complementation. Genetic mapping. Genetic screens as a basis for functional genomics. Deficiencies, EMS & X-ray-based mutagenesis screens. Creating alleles. Enhancer traps, EP-Lines, RNA-inheritance, FLP-FRT & Cre- Lox Systems. Behaviour mutant screens. Utility of the model organisms: *Escherichia coli*, *Arabidopsis thaliana*, *Caenorhabditis elegans*, *Drosophila melanogaster* & *Mus musculus*.

UNIT IV: Human Population Genetics and Genetic Counselling 13 Lectures

Human Genetics: Pedigree analysis; Karyotype, banding and nomenclature of chromosome subdivisions. Genetic disorders: chromosomal aneuploidy (Down, Turner and Klinefelter syndromes), chromosome translocation (Chronic Myeloid Leukemia) and deletion (“cry of cat” syndrome), gene mutation (sickle cell anemia). Genetic counselling, Gene isolation Manipulation and the techniques that revolutionized modern genetics.Transcription of mRNA Translation. Genetic code. Working with nucleic acids and proteins. Polymerase Chain Reaction. DNA Sequencing; Southern, Western & Northern Blots. *In situ* Hybridization, FISH, SNPs, RFLPs, ESTs, STS and Oligonucleotide arrays. Gene Cloning *vs* Animal Cloning, Nuclear transplantation, stem cells and IPS cells.

Recommended readings

1. Gardner, E.J. *et al.* (2006) Principles of Genetics (John Wiley).
2. Russell, P.J. (2010) Genetics (Benjamin Cummings).
3. Gardner, E.J., Simmons, M.J., Snustad, D.P. (2008). Principles of Genetics. (VIII edition) Wiley India.
4. Snustad, D.P. and Simmons, M.J. (2009). Principles of Genetics. (V edition) John Wiley
   and Sons Inc.
5. Klug, W.S., Cummings, M.R. and Spencer, C.A. (2012). Concepts of Genetics. (X edition) Benjamin Cummings.

6. Carroll S.B.; Doebley J.; Griffiths, A.J.F. and Wessler, S.R. (2018) An Introduction to Genetic Analysis. W. H. Freeman and Co. Ltd.

Practical

1. Application of probability in the law of segregation with coin tossing
2. Frequency of the following genetic traits in human: widow’s peak, attached ear lobe, dimple in chin, hypertrichosis, colour blindness, PTC tasting
3. Study of mode of inheritance of the following traits by pedigree charts – attached ear lobe, widow’s peak
4. Familiarization with techniques of handling *Drosophila*, identifying males and females; observing wild type and mutant (white eye, wing less) flies, and setting up cultures
5. Demonstration of law of segregation (monohybrid and test cross) sex-linked inheritance in *Drosophila* making a cross between white eye dumpy winged or sepia eyed and wild type flies (criss-cross inheritance)
6. Demonstration of lethal alleles using Curly (Cy) mutant in *Drosophila*
7. Demonstration of multiple allelism by showing mutants of white eye series in *Drosophila*
8. Study of structural chromosome aberrations (dicentric, ring chromosomes and inversions in polytene chromosomes) from prepared slides/photographs
9. Study of human karyotypes and numerical alterations (Down syndrome, Klinefelter syndrome and Turner syndrome)
10. Extraction of Genomic DNA from bacteria.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
IV	**CC-7**	**Biochemistry**	Theory:04 Practical: 02 Total: 06

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About the course

The course provides an introduction to the structure of biomolecules with emphasis on the techniques used for structure determination and analysis. The course covers basic aspects of sample preparation for analysis and aims to enlighten the students how structural information can be utilized for better understanding of biological processes.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand about the importance and scope of biochemistry.
- Understand the structure and biological significance of carbohydrates, amino acids, proteins, lipids and nucleic acids.
- Understand the structure and function of immunoglobulins.
- Understand the concept of enzyme, its mechanism of action and regulation.
- Understand the process of DNA replication, transcription and translation.
- Learn the preparation of models of peptides and nucleotides.
- Learn biochemical tests for amino acids, carbohydrates, proteins and nucleic acids.
- Learn measurement of enzyme activity and its kinetics.

<u>Theory</u>

UNIT I: Introduction to Biochemistry, Carbohydrates 12 Lectures

Introduction, scope and importance of Biochemistry. Principle of bimolecular organization, configuration and conformation. Water as biological solvent. Carbohydrates: Structure and biological importance. Classification - Reducing and non-reducing sugars, monosaccharides, Oligosaccharides (Disaccharides), polysaccharides (peptidoglycans and glycosaminoglycans). Catabolism of carbohydrates and ATP production, Glycolysis, Krebs cycle, Electron transport chain and ATP synthesis Phosphate pentose pathway, Gluconeogenesis, Glycogenolysis and Glycogenesis.

UNIT II: Lipids: Structure and Biological significance 13 Lectures

Lipids: Structure and Biological significance. Fatty acids- Types and nomenclature (saturated and unsaturated). Classification- Triglycerides, Phospholipids, Sphingolipids, Cholesterol, β-oxidation and omega -oxidation of saturated fatty acids with even and odd number of carbon atoms. Biosynthesis of palmitic acid; Ketogenesis.

UNIT III: Protein structure and metabolism 16 Lectures

Proteins: Composition and Biological significance. Amino acids -Structure, classification and properties, Ionization, titration curve, pK and pI. Physiological importance of essential and non-essential amino acids. Catabolism of amino acids: Transamination, Deamination, Urea cycle. Structural organization, N-terminal analysis: Sanger and Edman's reactions, denaturation and degradation, functions and diversity. Immunoglobulin: Basic structure and classes, functions and antigenic determinants. Enzymes: Nomenclature and classification, general properties, specificity, cofactors, isozymes. Mechanism of enzyme action (ES complex and lowering of activation energy, chemical catalysis). Kinetics (determination of Km and Vmax using Michaelis-Menten and Lineweaver-Burk plots). Regulation of enzyme activity, inhibition, allosteric regulation, role of covalent modifications, ribozymes and concept of abzymes.

UNIT IV: Nucleic acids and mechanisms of replication, transcription and translation 11 Lectures

Structure -Bases, nucleosides and nucleotides. DNA structure: Conformation (A, B and Z), DNA double helix (Watson and Crick model). DNA and RNA as genetic material. Organization of nucleosomes and higher order structure. DNA replication: Machinery and Basic mechanism (Prokaryotes). Transcriptional unit and basic mechanism of transcription (Prokaryotes). Genetic code and basic mechanism of translation (Prokaryotes). Introduction to recombinant DNA techniques and their applications. Determination of atomic structure using X-ray crystallography and graphic tools.

Recommended readings

1. Nelson, D.L. & Cox, M.M. (2017) Lehninger Principles of Biochemistry (7th edition) Worth.
2. Berg, J.M.; Tymoczko, J.L. and Stryer, L. (2012) Biochemistry (7th edition) Freeman.
3. Zubay, G. (2017) Biochemistry (4th edition) McGraw-Hill.
4. Conn, E.E.; Stumpf, P.K.; Bruening, G. and Doi, R.H. (2006) Principles of Biochemistry (5th edition) Wiley.

Practical

1. Preparation of models of amino acids and dipeptides.
2. Ninhydrin test for α-amino acids.
3. Determination of pK and pI values of glycine.
4. Benedict's test for reducing sugars.
5. Iodine test for starch.
6. Determination of acid value of oil.
7. Preparation of models of nitrogenous bases, nucleosides and nucleotides.
8. Qualitative test for DNA & RNA.
9. Determination of the activity of enzyme (Urease).
    9.1. Effect of [S] and determination of Km and Vmax.
    9.2. Effect of temperature.
    9.3. Effect of time.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
IV	**CC-8**	**Behaviour and Chronobiology**	Theory:04 Practical: 02 Total: 06

About the course

The course aims to explain the natural behaviour patterns, how the behaviour varies among individuals and species (wild, domestic, and captive), how current and past environments and ecology influence not only behaviour, but also the underlying gene-environment interactions that shape it.

Learning outcomes

After successfully completing this course, the students will be able to:

- Learn a wide range of theoretical and practical techniques used to study animal behaviour.
- Develop skills, concepts and experience to understand all aspects of animal behaviour.
- Objectively understand and evaluate information about animal behaviour and ecology encountered in our daily lives.
- Understand and be able to objectively evaluate the role of behaviour in the protection and conservation of animals in the wild.
- Consider and evaluate behaviour of all animals, including humans, in the complex ecological world, including the urban environment

<u>Theory</u>

UNIT I: Behaviour and the response invoking stimuli **12 Lectures**

Animal behaviour. Scope and importance of study. Proximate and ultimate causes of behavior and the evolutionary approach to studying behaviour. Methods and recording of a behavior Types of stimuli invoking response: internal and external cues. Patterns of behaviour: Kinds of behaviour: foraging behaviour, Territorial behaviour. Mate selection and courtship behaviour. Parental care, defensive behaviour. Allelomimetic and maladaptive (abnormal) behaviour. Stereotyped Behaviours (Orientation, Reflexes); Innate/ Instinct behaviour. vs. Learnt Behaviour.

UNIT II: Communication and regulation of behaviour **13 Lectures**

Social organization (e.g., Honey bee, Termites etc.). Communication in living in groups. Evolution of sociality, eusocial organisation. Genetic basis of behaviour. Regulation of behaviour: Neural control: kineses, taxes, simple reflexes. Sensory processing: toad prey capture, sound localization (owls), echolocation (bats). Hormonal control. Biological clocks: Advantages of biological rhythms. Circadian and circannual rhythms. Photoperiodism, tidal, solar and lunar rhythms, entrainments. Biological oscillation: the concept of Average, amplitude, phase and period, Role of melatonin. Applications of Chronobiology. Chronopharmacology, Chronomedicine, Chronotherapy. Migratory behaviour in birds and fishes.

UNIT III: Innate behaviour; Evolution of reproductive behaviour **13 Lectures**

Innate behaviour: communication (primates, bees and ants). Decision making. Motor Output: leech swimming/crawling, escape behavior, cricket vocalizations. Sensorimotor integration: electric fish, bird song instinct and motivation. territorial behaviour, schooling behaviour. Displacement activities, Ritualization, Habitat selection, food selection and foraging behaviour in African ungulates. Mimicry and colouration. Evolution of reproductive behavior, mating systems and parental care. Asymmetry in sex, sexual dimorphism.

Unit IV: Learning behaviour; conditioning; socio-biology **14 Lectures**

Learning (Learnt behaviour): habituation, imprinting, conditioned reflex, trial and error learning, latent learning, insight learning. Types of learning -Habituation, Imprinting and types of imprinting -filial and sexual, Classical conditioning, Instrumental learning and insight learning. Social behaviour: Social and cultural transmission of Behaviour; aggregation, group selection, kin selection, altruism. Social organization (e.g., Honeybee, Naked Mole Rat and Monkey). Elements of Socio-biology: Selfishness, cooperation, altruism, kinship and inclusive fitness

Recommended readings

1. McFarland, D. (1999) Animal Behaviour (3rd edition) Pitman Publishing Limited, London, UK.

2. Manning, A. and Dawkins, M. S. (2012) An Introduction to Animal Behaviour (6th edition) Cambridge, University Press, UK

3. Alcock, J. (2005) Animal Behaviour (8th edition) Sinauer Associate Inc., USA.

4. Sherman, P. W. and Alcock, J. (2013) Exploring Animal Behaviour (6th edition) Sinauer Associate Inc., Massachusetts, USA.

5. Dunlap, J. C.; Loros, J.J. and DeCoursey, P. J. (2009) Chronobiology Biological Timekeeping (1st edition) Sinauer Associates, Inc. Publishers, Sunderland, MA, USA.

6. Kumar, V. (2002). Biological Rhythms: Narosa Publishing House, Delhi/ Springer - Verlag, Germany.

<u>Practical</u>

1. Orientation of an animal to light.
2. Constructing an ethogram.
3. Chemical communication in ants.
4. Selective predation of coloured prey items.
5. Predatory behaviour of a carnivorous animal.
6. Nests and nesting habits of the birds and social insects
7. To study the behavioural responses of wood lice to dry and humid conditions.
8. To study geotaxis behaviour in earthworm.
9. To study the phototaxis behaviour in insect larvae.
10. Study of circadian functions in humans (daily eating, sleep and temperature patterns).
11. Visit to Forest/ Wild life Sanctuary/Biodiversity Park/Zoological Park to study behavioural activities of animals and prepare a short report.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
V	**CC-9**	**Ecology**	Theory:04 Practical: 02 Total: 06

About the course

This course will take students on a journey through the physical workings of the Earth, the interactions between species and their environments. The course highlights on some of the important aspects *viz*. growth and survival of populations and communities in different habitats, energy flow in the ecosystems, interactions between the communities, exclusion of niches and consequences of changing environment on the biodiversity.

Learning outcomes

After successfully completing this course, the students will be able to:

- Know the evolutionary and functional basis of animal ecology.
- Understand what makes the scientific study of animal ecology a crucial and exciting endeavour.
- Engage in field-based research activities to understand well the theoretical aspects taught besides learning techniques for gathering data in the field.
- Analyse a biological problem, derive testable hypotheses and then design experiments and put the tests into practice.
- Solve the environmental problems involving interaction of humans and natural systems at local or global level.

Theory

UNIT I: An overview of Ecology, Ecosystems and Biomes **13 Lectures**

Introduction and scope of Ecology. Multidisciplinary relevance in current perspective. Structure and function of ecosystem; Abiotic factors affecting survival and sustenance of organisms e.g., water, temperature, light, pH and salinity. Role of limiting factors in survival of biotic components. Major ecosystems of the world: Ecological features, limiting factors, zonation and classification of organisms of fresh water and marine ecosystems. Introduction to Biome: Ecological features of Tundra, Desert, Savannah and Tropical Rain forest Biomes.Energy flow in ecosystem, food chain and food web. Productivity. Mineralization and recycling of nutrients: C, N, P & S.

UNIT II: Population ecology; Human population growth 13 Lectures

Ecology of populations: Unitary and Modular populations. Unique and group attributes of population: Density, natality, mortality, life tables, fecundity tables, survivorship curves. Unique and group attributes of population: mortality, age ratio, sex ratio, dispersal. Factors regulating population dispersal and growth: Exponential and logistic growth. Population regulation: density-dependent and independent factors; r and K strategies. Metapopulations, demes and interdemic extinction. Life history strategies: reproductive effort, offspring size and cost-benefit ratio. Ecological efficiencies. Human population growth: Impacts on environment, carrying capacity, human health and welfare.

UNIT III: Biotic community, characteristics and attributes 13 Lectures

Community characteristics: stratification; Dominance, diversity, species richness, abundance, Evenness, Similarity. Diversity and food-web indices. Ecotone and edge effect; Types of interaction: Positive interactions: commensalism, proto-cooperation, and mutualism. Negative interactions: parasitism and allelopathy; predation and predator-prey dynamics; herbivory. Interspecific competition and coexistence, Inter and intra-specific; abundance. Niche overlap and segregation. Gause's Principle with laboratory and field examples. Ecological succession: Definition, Process, types, theories of succession.

UNIT IV: Environmental degradation; Environmental movement etc. 13 Lectures

Environmental ethics; Pollution: Air, water and noise pollution and their control; Natural resources: Mineral, water and forest, their significance and conservation; Types of biodiversity, Hotspots, benefit and threat of conservation strategies; Biodiversity: status, monitoring and documentation; major drivers of biodiversity change; Biodiversity mapping using GPS, GIS and remote sensing. Ecosystem and biodiversity services: Ecological, economic, social, ethical, aesthetic and Informational value. Application of ecology in management and Conservation programmes. Role of gender and cultures in environmental conservation. Environmental movements: Bishnois. Chipko, Silent valley, Big dam movements. Environmental education and public awareness

Recommended readings

1. Colinvaux, P. A. (1993) Ecology (2nd edition) Wiley, John and Sons, Inc.
2. Krebs, C. J. (2001) Ecology (6th edition) Benjamin Cummings.
3. Odum, E.P., (2008) Fundamentals of Ecology. Indian Edition. Brooks/Cole.
4. Ricklefs, R.E. (2000) Ecology (5th edition) Chiron Press.
5. Southwood, T.R.E. and Henderson, P.A. (2000) Ecologial Methods (3rd edition) Blackwell Sci.
6. Kendeigh, F C. (1984) Ecology with Special Reference to Animal and Man. Prentice Hall Inc.
7. Stiling, P. D. (2012) Ecology Companion Site: Global Insights and Investigations. McGraw Hill Education.

Practical

1. To measure microclimatic variables *viz*., temperature, humidity and light conditions in a microhabitat.
2. Making an ecosystem in a wide-mouthed bottle.
3. Constructing a food web by observing and collecting organisms from a given area.
4. Preparing and clearly present an essay based on the evaluation of 4-7 publications
5. Studying the impact of herbivore on plant species (planted in pots under specific conditions)
6. Constructing distribution map of species of a genus through GPS by estimating the coordinates.
7. Investigation of volatile inhibitory substances produced through decomposition of plant debris and root exudates.
8. Estimation of the ratio of the producers and consumers.
9. Studying insect diversity in a habitat.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
V	**CC-10**	**Molecular Biology**	Theory:04 Practical: 02 Total: 06

About the course

The course provides an insight into the life processes at the subcellular and molecular levels. Other important aspects include DNA and molecular genetics including gene cloning, sequencing and gene mapping in addition to the powerful techniques that revolutionized the pharmaceutical, health and agricultural industries.

Learning outcomes

After successfully completing this course, the students will be able to:

- Develop an understanding of concepts, mechanisms and evolutionary significance and relevance of molecular biology in the current scenario.
- Get well versed in recombinant DNA technology which holds application in biomedical & genomic science, agriculture, environment management, etc. Therefore, a fundamental understanding of Molecular Biology will help in career building in all these fields.
- Apply their knowledge in problem solving and future course of their career development in higher education and research.
- Get new avenues of joining research in related areas such as therapeutic strategies or related opportunities in industry.

Theory

Unit -1: Central dogma; detailed information on nucleic acids 13 Lectures

Introduction to Molecular Biology, Central Dogma of Molecular Biology. Origin and evolution of life/ Prokaryotic and Eukaryotic Genes and Genomes, Model Genomes. Structure and Function of DNA, DNA forms: Plasmid DNA, Genomic DNA and Repetitive DNA. Conformation, Structure and Topology of DNA, DNA-modifications, DNA methylation. DNA-Protein interaction, DNA sequencing, DNA polymorphisms. Structure and Function of RNA, Ribosomal RNA (rRNA), Transfer RNA (tRNA), Messenger RNA (mRNA), Noncoding RNA.

Unit –II: Chromosomes; DNA replication, recombination, repair etc. 13 Lectures

Chromosomes, Chromatin, Histones, Histone-modifications. DNA Replication, plasmid DNA replication and genomic DNA replication. DNA polymerases, other regulatory proteins, centromeric and telomeric DNA replication, DNA replication and cell cycle regulation. Mutation, DNA-damaging agents, DNA recombination. DNA repair, mismatch repair, single strand- and double strand DNA repair

Unit –III: RNA transcription, processing, editing, splicing etc. 13 Lectures

Transcription, RNA polymerase I, II, III, transcription factors, chromatin remodeling. Regulation of gene expression in prokaryotes and eukaryotes. RNA processing, splicing of hnRNA into mRNA, 5'-capping and 3'-polyadenylation of mRNA, rRNA and tRNA modifications and processing. RNA editing, alternative splicing, trans-splicing, miRNA, siRNA, piRNA, lncRNA, RNA-protein complex.

Unit –IV: Ribosomes: Role in cell sustenance. 13 Lectures

Ribosomes, Genetic Code, triplet codons, Wobble base, synonymous codons, degeneracy of codons, missense-, nonsense- and frame shift mutations. Translation, protein synthesis in *E. coli* and eukaryotic cells. Aminoacylation of tRNA, initiation, elongation, peptide bond formation, translocation, termination, recycling of ribosome, regulation of protein synthesis and codon bias. Post-translational modifications and processing of proteins, large protein-protein complexes and protein trafficking

Recommended readings

1. Watson, J.D. *et al.* (2013) Molecular Biology of the Gene (7th edition) CSHL Press Pearson.
2. Green, M. R and Sambrook, J. (2012) Molecular Cloning: a Laboratory Protocol (4th edition) CSHL Press.
3. Walter, P. (2007) Molecular Biology of the Cell (5th edition) Garland Science.

Practical

1. Preparation of ball and stick model for B-DNA molecule (A=T and G=C base pairs).
2. Isolation of genomic DNA by ethanol precipitation method.
3. Preparation of LB-agar plates (with and without 100 microgram/ml Ampicillin and 10 microgram/ml Tetracycline), streaking of *E. coli* DH5alpha strain (normal) and transformed with plasmids [Ampicillin-resistant (pBluescript) and Tetracycline-resistant (pBR322)].
4. Isolation of the plasmid DNA from the *E. coli* culture by alkaline lysis method.
5. Agarose gel electrophoresis of the plasmid DNA and the genomic DNA.
6. Staining of β-galactosidase activity in the DH5alpha cells with pBluescript plasmid by IPTG+X-Gal as an example of induction of gene expression.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
V	**CC-11**	**Biotechniques**	Theory:04 Practical: 02 Total: 06

About the course

This is the only laboratory course taught independently of lecture courses. It has full hands on approach to expose the students to modern techniques and methodologies. The diverse techniques from microscopy to spectroscopy, calorimetry, chromatography ELISA, tissue culture to cloning etc. are included to make the student well versed with these protocols and methods.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand the purpose of the technique, its proper use and possible modifications/ improvement.
- Learn the theoretical basis of technique, its principle of working and its correct application.
- Learn the construction repair and adjustment of any equipment required for a technique.
- Learn the accuracy of technique.
- Learn the maintenance laboratory equipments/ tools, safety hazards and precautions.
- Understand the technique of cell and tissue culture. Learn the preparation of solution of given percentage and molarity.
- Understand the process of preparation of buffer. Learn the techniques of separation of amino acids, proteins and nucleic acids.

Theory

UNIT I : Microscopy and Microtomy **13 Lectures**

Microscopy: Introduction to Microscopy. Definitions-Resolving Power, Limit of Resolution and Magnification, Numerical Aperture. Types of microscopes. bright field, dark-field, phase contrast. Basic principles of Light, Electron, Fluorescence and Confocal Microscopy. Measurements, Drawings and photomicrography. Microtomy: Tissue preparation, fixation, block preparation, sectioning, staining, dehydration and mounting.

UNIT II : Tools and techniques in Biochemistry and Physiology 13 Lectures

Biochemistry and Physiology: Physiological Salines, Buffers and the use of pH meter. Extraction of Tissue Glycogen, Proteins, Lipids and Nucleic Acids by Graaf's Method. Subcellular Fractionation by Differential Centrifugation. Basic Principle and Application of Colorimetry and Spectrophotometry, Beer-Lambert's Law. Principle and applications of Electrophoresis: Separation of Biomolecules by Native PAGE, 2D PAGE. Agarose gel electrophoresis. Principle and Applications of Paper chromatography, Thin layer chromatography, Gel-filtration chromatography.

.**UNIT III : Tools and Techniques in Endocrinology and immunology 13 Lectures**

Immunology and Endocrinology: Introduction to Antigens, Antibodies, Adjuvants. Raising Polyclonal and Monoclonal Antibodies. Antigen-Antibody Interactions- Immunodiffusion, Ouchterlony's Double Immunodiffusion, Counter-Current, Immunoelectrophoresis, Western Blotting, ELISA, RIA. Principle & Working of ELISA, Reader, Hormones assay methods. Application of Immunological techniques in disease diagnosis. Tracer techniques: Principle and Applications, Unit of radioactivity, half-life and measurement of radioactivity.

UNIT IV: Cell culture, maintenance of Laboratory animals 13 Lectures

Cell Culture and Laboratory Animals**:** Cell culture and its basic requirements. Culture media-Nutrient and Non-nutrient, commonly used media for human cell lines. Sterilization of culture wares and Media, laminar flow. Types of animal cell culture, cell viability testing. cryopreservation. Lymphocyte culture. Cell harvesting and Storage Methods. *In Vitro* culture of *Entamoeba histolytica*, *Coenorhabditis elegans*. Maintenance and Handling of laboratory rats and rabbits. Bioethics.

Recommended readings

1. Boyer, R. (2000) Modern Experimental Biochemistry (3rd edition) Benjamin-Cummings.
2. Pearse, A.G.E. (1980-1993) Histochemistry - Theoretical and applied, Volume I-III, Churchill-Livingstones.
3. Plummer, D. (2017) An Introduction to Practical Biochemistry (3^{rd} edition) McGraw Hill.
4. Wilson, K. and Walker, J. (2010) Experimental Biochemistry, Cambridge.

Practical

1. Preparation of buffer and determination of pH.
2. Identification of amino acids in the mixture using paper chromatography.

3. Verification of laws of spectrophotometry.
4. Separation of proteins using SDS-PAGE.
5. Tissue fixation, paraffin block preparation, sectioning.
6. Preparation of permanent slides of microscopic organisms/ small insects.
7. Demonstration of bright field, phase contrast, fluorescence, confocal and electron microscopes.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
VI	**CC-12**	**Microbiology, Parasitology and Immunology**	Theory:04 Practical: 02 Total: 06

About the course

This is a composite course with remarkable utility and importance. Microbiology being the study of microorganisms such as viruses, bacteria etc., covers theoretical studies and practical proficiency training which may help in their placement at a clinical microbiological laboratory. Parasitology component takes care of the parasites and parasitism, emphasizing the influence of parasites on the ecology and evolution of free living species, and the role of parasites in global, public, health. Immunology part provides the students with the fundamental knowledge of the immune system and its protective roles against diseases.

Learning outcomes

After successfully completing this course, the students will be able to:

- Carry out common procedures for culturing, purifying and diagnostics of micro-organisms understand the disease-causing potential of bacteria and viruses, and the responses of the immune system.
- Summarise and orally present current microbiological problem areas.
- Describe the mechanisms for transmission, virulence and pathogenicity in pathogenic micro-organisms.
- Diagnose the causative agents, describe pathogenesis and treatment for important diseases like malaria, leishmaniasis, trypanosomiasis, toxoplasmosis, schistosomiasis, cysticercosis, filariasis etc.
- Assess the importance of incidence, prevalence and epidemiology in microbiological diagnostic activities.
- Know how resistance development and resistance transfer occur.

- Identify the major cellular and tissue components which comprise the innate and adaptive immune system.
- Understand how are immune responses by CD4 and CD8 T cells, and B cells, initiated and regulated.
- Understand how does the immune system distinguish self from non-self .
- Gain experience at reading and evaluating the scientific literature in the area.

Theory

UNIT: Microbiology: A brief account of pathogenic bacteria and viruses. 13 Lectures

Brief history of microbiology- germ theory of disease, discovery of penicillin. Diversity of microbes- viruses and bacteria. Host pathogen interaction: invasion, antigenic heterogeneity, toxins and enzymes secretions. Kinetics of bacterial growth and staining techniques. Viral diseases: polio, rabies, hepatitis, influenza, dengue, AIDS, chicken pox, swine flu, chikungunya with emphasis on their causative agents, pathogenesis, diagnosis, prophylaxis and chemotherapy. Bacterial diseases caused by *Bacillus anthracis, Streptococcus pyogenes, Streptococcus pneumoniae, Salmonella typhi, Escherichia coli, Helicobacter pylori, Mycobacterium tuberculosis, Vibrio cholerae.* Fungal diseases: Ringworm infection, aspergillosis, candidiasis.

UNIT-II: Parasitology: an overview of common parasitic infections. 13 Lectures

Introduction to parasites and parasitic diseases. Mode of transmission, portal of entry and implications of parasitism. Parasitic adaptations. Concept of zoonotic diseases. Protozoan diseases of medical importance: amoebiasis, giardiasis, malaria, trypanosomiasis, leshmaniasis and toxoplasmosis. Helminthic diseases of medical importance: Schistosomiasis, taeniasis, echinococcosis, ascariasis, enterobiasis, dracunculiasis and filariasis.

UNIT-III: Immunology: Immune mechanism and related pathways. 13 Lectures

Definition and classification. Cells and organs of immune system- primary and secondary lymphoid organs. Innate immunity: First and second lines of defense. Characteristics of antigen- antigenicity and immunogenicity, epitopes, haptens, adjuvant. Factors influencing immunogenicity. Classical and molecular structure of immunoglobulin. Classification, properties and functions of immunoglobulins. Antigenic determinants: isotype, allotype and idiotype. Antigen and antibody interactions, affinity, avidity. Complement system (Classical, alternative and lectin pathways).

UNIT-IV: Acquired immunity, Hypersensitivity and autoimmune disorders 13 Lectures

Acquired immunity: Humoral and cell mediated immune response. Role of B and T cell in immunity. Receptors, activation and differentiation of B and T cells. Cytokines: Properties and function. MHC complex and molecules with classification and function. Graft rejection. Antigen processing and their presentation. Hypersensitivity: Gell and Coomb's classification with mechanism and examples. Autoimmune disorders. Hybridoma technology, monoclonal antibodies, immunotoxins and their applications.

Recommended readings

1. Jawetz, M. and Adelberg (2015) Medical Microbiology (27th edition)
2. Chatterjee, K.D (2015) Parasitology (13th edition)
3. Goldsby, R.A.; Kindt, T.J. and Kuby, J. (2006) Immunology (6th edition).
4. Roitt, I.; Brostoff, J. and Male, D. (2012) Immunology (8th edition).

Practical

1. Study of permanent slides and specimens of parasitic protozoans and helminthes.
2. Pathological examination of sputum, blood, urine and stool.
3. Blood: Erythrocyte Sedimentation Rate (ESR), Haematocrit.
4. Staining and identification of Gram positive and Gram negative bacteria.
5. Preparation of thin and thick blood films to diagnose *Plasmodium* infections.
6. Preparation of temporary and permanent slides of faecal matter by saline preparation and concentration techniques to identify cysts of parasitic protozoans and helminthes eggs.
7. Demonstration of antigen-antibody interaction in gel.
8. Separation of γ-globulin by salt precipitation.

Group discussion or Seminar presentation on one or two related topics to those provided in the list (page no. 25-28).

Semester	Core course	Course Title	Credit
VI	**CC-XIII**	**Biostatistics and Bioinformatics**	Theory:04 Practical: 02 Total: 06

About the course

The course is aimed at introducing the application of bioinformatics and statistics in biology. The course gives an insight into the key concepts and methods used in bioinformatics; and computer storage, retrieval, analysis, visualization and distribution of information data related to biological macromolecules like DNA, RNA and proteins. It provides foundation on statistical methods to enable students to compute and interpret basic statistical parameters. As an interdisciplinary field it integrates biology, computer science, chemistry and statistics together sequence analysis structure analysis and functional analysis of biological data.

Learning outcomes

After successfully completing this course, the students will be able to:

- Know the theory behind fundamental bioinformatics analysis methods.
- Be familiar with widely used bioinformatics databases.
- Know basic concepts of probability and statistics.
- Describe statistical methods and probability distributions relevant for molecular biology data.
- Know the applications and limitations of different bioinformatics and statistical methods.
- Perform and interpret bioinformatics and statistical analyses with real molecular biology data.
- Acquire knowledge of various databases of proteins, nucleic acids. Primary, secondary and composite databases. BLAST, FASTA, DOT PLOT
- Make phylogenetic predictions or prediction of structure of proteins and nucleic acids
- Develop understanding in Primer designing
- Understand data mining tool and its practical application in a case study
- Apply the knowledge in future course of their career development in higher education and research.

Theory

UNIT I: Data collection, distribution, presentation, authentication and analysis

13 Lectures

Collection and classification of data. Graphical representation of data: Pie chart, Bar diagram, Histogram, Frequency polygon. Cumulative frequency curve (Ogive), Box plot. Probability theory: Binomial distribution, Poisson distributions. Measures of central tendency: Arithmetic Mean, Median, Mode; Measures of dispersion: Variance, Standard deviation and Standard error, Concept of Coefficient of variation.

UNIT II: Correlation, regression, analysis of variance etc. **12 Lectures**

Correlation: Types of correlation, Calculation of correlation in continuous data and ordinal data. Regression: Linear regression, regression coefficient. Analysis of variance (ANOVA): One way, post-hoc tests. Hypothesis testing: Parametric tests (Paired and unpaired t-test, z-test, F-test) & Non Parametric tests (Chi-square test, Mann-Whitney U-test)

UNIT III: Basics of IT; Data archiving systems etc. **12 Lectures**

Introduction and scope of bioinformatics: concept of digital laboratory. Basics of information technology, computer, operating systems, network. Concept of internet protocol (TCP/IP), hypertext, home-page, web-page and uniform resource locators (URL). Introduction to data archiving systems (FASTA format, Accession, and GI-Number)

UNIT IV: Data base management: software, packages and tools **15 Lectures**

Basic features and management systems of following: Nucleic acid sequences databases, Genome databases, Protein sequence, structures and interacting proteins databases, Literature databases, Biodiversity and ecosystem based databases. Introduction to data retrieval systems, Search engines, Entrez, sequence retrieval system (SRS) and protein identification resource (PIR). Introduction to molecular sequence analysis software packages and tools, Prediction of motifs, folds and domains, Sequence alignments (BLAST and Clustal W) and phylogenetic trees (PHYLIP). Applications of bioinformatics: Clinical informatics, Cheminformatic resources and pharmacoinformatics

Recommended readings

1. Daniel, W.W. (2012) Biostatistics: A Foundation for Analysis in Health Sciences (10th edition) John Wiley.
2. Milton, J.S. & Tsokos, J.O. (1992) Statistical Methods in the Biological and Health Sciences (2nd edition) McGraw Hill.
3. Zar, J.H. (2013) Biostatistical Analysis (5th edition) Pearson.

4. Barnes, M.R. and Gray, I.C. (2003) Bioinformatics for geneticists, Wiley.
5. Mount, D.W. (2006) Bioinformatics (2nd edition) CBS.

Practical

1. Calculation of mean, standard deviation and standard error.
2. Calculation of correlation coefficient values and finding out the probability
3. Calculation of ‘F’ value and finding out the probability value for the F value.
4. Student’s t-test: Independent and dependent. Hand calculation and calculation using MS Excel.
5. ANOVA and Tukey’s HSD: Hand calculation and calculation using MS Excel.
6. Handling and interpretation of Nucleic acid and protein databases.
7. Sequence retrieval from databases.
8. Pair-wise alignment of sequences (BLAST) and interpretation of the output
9. Sequence homology and Gene annotation. Translation of a nucleotide sequence and selection of the correct reading frame of the polypeptide from the output sequences
10. Construction of phylogenetic tree.
11. Comparative analysis of different databases in metabolomics.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Core course	Course Title	Credit
VI	**CC-XIV**	**Applied Zoology**	Theory:04 Practical: 02 Total: 06

About the course

The course is unique in highlighting the commercial and industrial significance/value of animals. It discusses the techniques/ methods of rearing of animals for commercial usage and the prerequisites for their successful maintenance and sustenance.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand the culture techniques of prawn, pearl and fish.
- Understand silkworms rearing and their products.
- Understand the Bee keeping equipments and apiary management.
- Understand dairy animals management, the breeds and diseases of goats and learn the testing of egg and milk quality.
- Learn various concepts of lac cultivation.
- Be aware of a broad array of career options and activities in human medicine, biomedical research and allied health professions.

Theory

UNIT I: Aquaculture **13 Lectures**

Aquaculture: Prawn culture: Culture of fresh water prawn; culture of marine prawn; preparation of farm. preservation and processing of prawn. Export of prawn. Pearl Culture, protocol followed; Fish Culture, Breeding Pond, Fish Seed, Hatching pond. Transport of fish fry to rearing ponds. Harvesting, preservation of fish. Composite fish farming. By products of fishing industry and common fish diseases.

UNIT II: Apiculture, Lac culture and Sericulture **13 Lectures**

Apiculture: Species of honey bees in India. Life history of *Apis*. Methods of Bee keeping. Bee products and their uses. Natural enemies and their control. Morphology and Biology of honey bees; social behavior of honey bees. Bee keeping and ancillary industries. Newton's Bee hive Extraction of honey. Medicinal value of honey; bee products. Importance of bee colonies in crop pollination. Lac culture: Lac insect and its life cycle. Cultivation of lac insect, host plants, processing and uses of lac. Sericulture: Types of silk; Silkworms and their host plants; Mulberry silkworm culture; Life history of silkworm; Natural enemies and their control

UNIT III: Dairy management and poultry farming 13 Lectures

Dairy: Introduction to common dairy animals. Techniques of dairy management. Milk and milk products. Cattle Diseases. Poultry: Types of breeds. Rearing method. Diseases and control measures. Breeds of fowl, Housing and Equipment, Deep litter System, Laying cages, Methods of brooding and Rearing, Debeaking. Management of growers, Layers, Broilers; Feed formulations for chicks, Diseases of fowl. Nutritive value of egg and meet. Incubation and hatching of eggs.

UNIT IV: Vermiculture; Maintenance of reared animals 13 Lectures

Vermiculture: Biology of *Eisenia foetida*. Rearing of earthworms, Equipments , devices used in vermiculture, Vermicompost Technology. Methods and products, Vermiwash Collection, Composition and use. Introduction and importance. Health care and maintenance of reared animals. Methods for analysis of blood. Methods for analysis of urine. Infectious diseases. Non-infectious diseases

Recommended readings

1. Shukla, G.S. and Upadhyaya, V.B. (1999-2000). Economic Zoology (Rastogi Publishers).
2. Mani, M.S. (2006). Insects, NBT, India.
3. Jabde, P.V. (2005) Text Book of Applied Zoology: Vermiculture, Apiculture, Sericulture, Lac culture.

<u>Practical</u>

1. Morphological characterization of common fish species.
2. Identification of two major carps – *Labeo rohita* and *Catla catla* and their life cycles.
3. Mounting of the sting apparatus.
4. Castes (through charts/specimens) study of bees
5. Worker honey bee with emphasis on leg modifications (through specimens/charts) and whole mount preparation of the 3 pairs of legs.

6. Life cycle of mulberry silkworm, *Bombyx mori* (model/chart/specimens) and life cycle of tasar silkworm, *Antheraea mylitta*.
7. External morphology and nomenclature of dairy animals. Determination of the specific gravity of milk by using a mercury lactometer.
8. Test for good quality eggs (Floating test, cracking test) and for fertilized and unfertilized eggs (Light test, Cracking test).
9. External morphology of poultry birds (model).
10. Project report on visit to dairy farm and visit to Poultry farm (Poultry management and Poultry breeds).

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Discipline Specific Elective Courses (DSE)

Semester	Course	Course Title	Credit
V/ VI	**DSE-1**	**Neuroscience**	Theory:04 Practical: 02 Total: 06

About the course

This course will start from the basics of the nervous system of invertebrates and will gradually move towards a more complex vertebrate nervous system. The students will also be taught about the types of synapse, neurotransmitters and their receptors besides other related aspects.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand the structure of brain and improved methods to study it.
- Develop treatments for neurodegenerative diseases (such as Alzheimer's and Parkinson's diseases) and mental illnesses.
- Understand the structure of different lobes of the brain and their corresponding functions.
- Understand intricacies of nerve impulse conduction.

Theory

Unit-I: Brain and spinal cord: Diversity in animals **12 Lectures**

General organization of nervous system: Invertebrate Nervous system: Organization of neurons in brain and ganglia of invertebrates nerve net, nerve plexus and ganglionated nervous system (hydra, starfish and earthworm); Functional organization of the human central nervous system, subdivisions of the CNS – spinal cord, medulla, pons, cerebellum, midbrain, diencephalon and cerebral hemispheres; Various lobes of the brain- fore brain, mid brain and hind brain and their functional familiarization; Limbic System and its related functions.

Unit-II: Nerve cells and action potential **12 Lectures**

Types of cells: neuronal, glial, ependymal and Schwann cells; Chemical basis of neural transmission- ionic basis of resting membrane potential: Donann's equilibrium experiments, Nernst's potential, Goldman's equation, sodium-potassium pump; Action Potential & propagation- Hodgkin and Huxley's model, voltage clamp experiment and the derivation and propagation of action potential.

Unit-III: Synaptic potential, neurotransmission etc. **14 Lectures**

Neuromuscular junctions, synapse and synaptic transmission. Synaptic potential and synaptic integration [Electrical and Chemical Synaptic Potential], Excitatory Post Synaptic Potential (EPSP), Inhibitory Post Synaptic Potential (IPSP). Neurotransmitters–Different types–catecholamines, amino acidergic and peptidergic neurotransmitters and their biosynthesis. Physiological role and pharmacological significance of neurotransmitters. Agonist and antagonist for neurotransmitters: Acetylcholine, Dopamine, GABA and Glutamate, Neuropeptide (Endorphin and Enkephalin). Neurotransmitter receptors: (a) Ionotropic receptors (nicotinic receptors of acetylcholine) (b) Metabotropic receptors like G-protein coupled receptors (D1 and D2 of dopamine and muscarinic receptors of acetylcholine).

Unit-IV: Neuropharmacology and molecular pathogenesis **14 Lectures**

Relationship of functional properties of neural systems with perception and behaviour; sensory systems, molecular basis of behaviour including learning and memory. Neuropharmacology: Introduction and its branches. Behavioural neuropharmacology: Effects of drug dependence and addiction. Molecular neuropharmacology: Neurons and neurochemical interactions for developing drugs having beneficial effects on neurological functions. Roles of neurotransmitters, neuropeptides, neurohormones and neuromodulators in neuropharmacology. Molecular pathogenesis of pain and neurodegenerative diseases such as Parkinson's, Alzheimer's, psychological disorders, addiction, etc.

Recommended readings

1. Baer, M.F. and Connors B.W. (2015) Neuroscience: Exploring the brain.
2. Byrne, J.H.; Heidelberg, R. and Waxham, M.N. (2014) From Molecules to Networks: An Introduction to Cellular and Molecular Neuroscience.

3. Kandel, E.R.; Schwartz, J.H. and Jessell, T.M. (2000) Principles of Neural Science (4th edition) McGraw Hill Companies
4. Simmons, J. and Young, D. (2003) Nerve Cells and Animal Behaviour (2nd edition) Peter. CUP.
5. Stahl, S.M. (2000) Essential Psychopharamacology- Neuroscientific Basis and Practical Applications (2nd edition) CUP
6. Vilayanur, S.R. and Blakeslee S. (1998) Phantoms in the Brain. Probing the Mysteries of the Human Mind.

Practical

1. Dissection and study of *Drosophila* nervous system using GFP reporter.
2. Observation and counting of *Drosophila* photoreceptor neurons in healthy and diseased condition.
3. Nerve Cell preparation from the spinal cord.
4. Study of neurons and/ or myelin by Nissl, Giemsa or Luxol Fast Blue staining.
5. Study of olfaction in *Drosophila*.
6. Study of novelty, anxiety and spatial learning in mice.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
V/ VI	**DSE-2**	**Endocrinology**	Theory:04 Practical: 02 Total: 06

About the course

The course envisages information on endocrine system with emphasis on the structure of hypothalamus and anterior pituitary. The associated hormones and the related disorders will be explained.

Learning outcomes

- Understand neurohormones and neurosecretions.
- Learn about hypothalamo and hypapophysial axis.
- Understand about different endocrine glands and their disorders.
- Understand the mechanism of hormone action.

Theory

Unit-I: The chemical messangers **8 Lectures**

Definition and classification of hormores. Endocrine, paracrine and autocrine modes of hormone delivery, Feedback mechanism.

Unit II: Hypothalamo-hypophysial Axis **20 Lectures**

Structure of pineal gland, Secretions and their functions in biological rhythms and reproduction; Structure of hypothalamus, Hypothalamic nuclei and their functions; Regulation of neuroendocrine glands, Feedback mechanisms; Structure of pituitary gland, Its hormones and their functions; Hypothalamo-hypophysial portal system; Disorders of pituitary gland.

Unit-III: Peripheral Endocrine Glands **20 Lectures**

Structure, Hormones, Functions and Regulation of Thyroid gland; Parathyroid & Adrenal glands; Pancreas; Ovary and Testis; Hormones in homeostasis; Disorders of endocrine glands.

Unit-IV: Regulation of Hormone Action **12 Lectures**

Hormone action at Cellular level: Hormone receptors; Transduction and regulation of Hormone action at Molecular level; Molecular mediators; Genetic control of hormone action.

Recommended readings

1. Turner, C. D. (1971) General Endocrinology, Pub- Saunders Toppan.
2. Nussey, S.S.; and Whitehead, S.A. (2001) Endocrinology: An Integrated Approach, Oxford: BIOS Scientific Publishers.
3. Hadley, M.E. and Levine J.E. (2007) Endocrinology (6th edition) Pearson Prentice-Hall, New Jersey.
4. David, O.N. (2013) Vertebrate Endocrinology.

Practical

1. Dissection and demonstration of Endocrine glands in laboratory bred rat*.
2. Study of the permanent slides of all the endocrine glands.
3. Compensatory ovarian/ adrenal hypertrophy in vivo bioassay in laboratory bred rat*.
4. Demonstration of Castration/ ovariectomy in laboratory bred rat*.
5. Estimation of plasma level of any hormone using ELISA.
6. Designing of primers of any hormone.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
V/ VI	**DSE-3**	**Nanobiology**	Theory:04 Practical: 02 Total: 06

About the course

This course is foundation for students who are interested in molecular materials, nanomaterials, biology-chemistry interface and self-assembly in chemical and biological systems.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand examples of Nano-science and Nano-biology in real life situations.
- Apply their knowledge in their career development in higher education, research and development.

Theory

Unit-I: Nanomaterials, scale scope and future **13 Lectures**

Introduction to Nanoscience, History of nanotechnology, and nanoscience in Nature; Molecular based study of condensed matter; low dimensional materials; Properties of nanomaterials: size, surface charge, conductivity, optical properties and biocompatibility.

Unit-II: Synthesis and characterization of nanomaterials, nanoparticles **13 Lectures**

Synthesis and characterization of nanomaterials, Fabrication of nanostructures, Top-down and bottom-up approaches and their biological relevance; Metallic nanoparticles, semiconductor, biopolymericnano-structures and magnetic nanoparticles; Synthesis and characterization of nanoparticles. Magnetic nanoparticles.

Unit-III: Composition and functional properties of nanostructures **13 Lectures**

Protein and peptide-based nanostructures, carbohydrate and nucleic acid based nanomaterials; Surface functionalization of gold, silver and other metallic nanoparticles and their applications; Biological application of Nanotechnology, Strategies to design biologically active nanostructure-bas/ed biomaterials. Interaction of nanoparticles with biomolecules; Determination of binding constants, effect on conformational and functional properties of biomolecules.

Unit-IV: Design and application of nanomaterials **13 Lectures**

Nanoparticle-based designing of potential therapeutics; Applications of rationally engineered proteins or peptides in the making of tissue scaffolds, biomaterials, Application of nanostructures in 3D-cell culture; Immobilized enzymes, drug delivery systems, targeted drug delivery systems; Nanomaterials as Biosensors, Cellular imaging tools and diagnostic applications.

Recommended readings

1. Pradeep, T. (2017) The Essentials: Understanding Nanoscience and Nanotechnology: Mc-Graw-Hill Education.
2. Phoenix, D.A. and Ahmad, W (2014) Nanobiotechnology. One Central Press Ltd.

Practical

1. Synthesis of silver nanoparticles by chemical method.
2. Synthesis of silver nanoparticle using microorganisms.
3. Synthesis of silver nanoparticles using plant extract
4. Synthesis of ZnO by hydrothermal method.
5. Synthesis of Polyanilinenanofibers by CBD method.
6. Synthesis of Fe2O3 by Sol-gel method.
7. Preparation of CdS by chemical bath deposition.
8. Electrodeposition of Cobalt thin films.
9. Preparation of CdSe by Successive Ionic Layer, Adsorption and Reaction(SILAR) method .
10. Cytotoxicity testing of nanoparticles.(antimicrobial Germination)

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
V/ VI	**DSE-4**	**Evolutionary Biology**	Theory:04 Practical: 02 Total: 06

About the course

The present course gives insight into the origin of life and the related evolutionary processes. The evolutionary theories and the process of species formation will be elaborated in view of the natural selection process.

Learning outcomes

After successfully completing this course, the students will be able to:

- Acquire an in-depth knowledge on the diversity and relationships in animal world.
- Develop a holistic appreciation on the phylogeny and adaptations in animals.
- Enable the students to understand the evolution of universe and life.
- Understanding on the process and theories in evolutionary biology.
- Develop an interest in the debates and discussion taking place in the field of evolutionary biology.

Theory

Unit-I: Origin of life and evidences of evolution **16 Lectures**

Evolution, science, and anti-science: the present threat to rationality. Life's Beginnings: Chemogeny, RNA world, Biogeny, Origin of photosynthesis, Evolution of eukaryotes; Historical review of evolutionary concept: Lamarckism, Darwinism, Neo-Darwinism. Evidences of Evolution: Fossil record (types of fossils, transitional forms, geological time scale, evolution of horse, Molecular (universality of genetic code and protein synthesising machinery, three domains of life, neutral theory of molecular evolution, molecular clock ,example of globin gene family, rRNA/cyt c; Sources of variations: Heritable variations and their role in evolution

Unit-II: How do evolutionary forces operate? **16 Lectures**

Hardy-Weinberg Law (statement and derivation of equation, application of law to human Population); Evolutionary forces upsetting H-W equilibrium; Natural selection (concept of fitness, selection coefficient, derivation of one unit of selection for a dominant allele, genetic load, mechanism of working, types of selection, density-dependent selection, heterozygous superiority, kin selection, adaptive resemblances, sexual selection. Genetic Drift (mechanism, founder's effect, bottleneck phenomenon; Role of Migration and Mutation in changing allele frequencies

Unit-III: Products of evolution: speciation mechanisms **8 Lectures**

Micro evolutionary changes (inter-population variations, clines, races, Species concept, Isolating mechanisms, modes of speciation—allopatric, sympatric, Adaptive radiation / macroevolution (exemplified by Galapagos finches; Extinctions, Back ground and mass extinctions (causes and effects), detailed example of K-T extinction

Unit-IV: Origin and evolution of man and the interpretation method **12 Lectures**

Origin and evolution of man, Unique hominin characteristics contrasted with primate characteristics, primate phylogeny from *Dryopithecus* leading to *Homo sapiens*, molecular analysis of human origin; Phylogenetic trees, Multiple sequence alignment, construction of phylogenetic trees, interpretation of trees.

Recommended readings

1. Ridley, M (2004) Evolution (3rd edition) Blackwell publishing
2. Hall, B.K. and Hallgrimson, B (2008) Evolution (4th edition) Jones and Barlett Publishers
3. Campbell, N.A. and Reece J.B (2011) Biology (9th edition) Pearson, Benjamin, Cummings
4. Douglas, J.F. (1997) Evolutionary Biology. Sinauer Associates.
5. Pevsner, J. (2009) Bioinformatics and Functional Genomics (2nd edition) Wiley-Blackwell.

Practical

1. Study of fossils from models/ pictures.

2. Study of homology and analogy from suitable specimens.
3. Study and verification of Hardy-Weinberg Law by chi square analysis.
4. Demonstration of role of natural selection and genetic drift in changing allele frequencies using simulation studies.
5. Graphical representation and interpretation of data of height/ weight of a sample. of 100 humans in relation to their age and sex.
6. Construction of phylogenetic trees with the help of bioinformatics tools (Clustal X, Phylip, NJ) and its interpretation.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
V/ VI	**DSE-5**	**Mammalian Physiology**	Theory:04 Practical: 02 Total: 06

About the course

The course deals with various physiological functions in mammals. It also gives an account of the metabolic/ biochemical pathways and the probable impact of environment on them.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand the physiology at cellular and system levels.
- Understand the mechanism and regulation of breathing, oxygen consumption and determination of respiratory quotient.
- Understand how mammalian body gets nutrition from different biomolecules.
- Understand the process of digestion and excretion.
- Understand the organization of nervous system and process of nerve conduction.
- Understand the process of vision and hearing.
- Understand the process of muscle contraction.
- Learn the determination of hemoglobin content, blood groups and blood pressure.

Theory

Unit-I: An overview of respiration and circulation in mammals **12 Lectures**

Respiration: Mechanism and regulation of breathing; Transport of oxygen and carbon dioxide; Respiratory quotient. Circulation: Blood buffers, blood groups, blood cells, cardiac cycle, Haemopoiesis, homeostasis.

Unit-II: An overview of digestion and excretion in mammals **10 Lectures**

Nutrition and Digestion: Balanced diet; Digestion and absorption of carbohydrates, proteins and fats; Gastrointestinal hormones: role in digestion. Excretion: Nephron; urine formation; Regulation of urine formation: role of renin, ADH, aldosterone.

Unit-III: An overview of nervous system and coordination in mammals 16 Lectures

Nervous System: Organization, neuron and glial cells- types and structure; Synapses – types and transmission, resting membrane potential: genesis; Action potential: initiation and conduction. Vision: Structure of eye, retinal components, and photoreceptors: ionic basis of potential generation. Hearing: Structure of ear, mechanoreceptor: ionic basis of potential generation.

Unit-IV: An overview of Muscular system and muscle contraction in mammals

11 Lectures

Muscles: Types, Ultra structure of skeletal, smooth and cardiac muscles, muscle proteins; Neuromuscular junction; Molecular and chemical basis of muscle contraction; Characteristics of muscle twitch, tetanus and fatigue, isotonic and isometric contractions.

Recommended readings

1. Barret, K.; Brooks, H.; Boitano, S. and Barman, S. (2010) Ganong's Review of Medical Physiology (23rd edition) Lange Medical.
2. Guyton, A.C. and Hall, J.E. (2006) A text book of Medical Physiology (11th edition) Saunders.
3. Keele, C.A. & Neil, E. (1989) Samson Wright's Applied Physiology (13th edition) Oxford.

Practical

1. Preparation of temporary mounts: Blood film, Squamous epithelium, Striated muscle fibres and nerve cells.
2. Counting of white blood corpuscles and red blood corpuscles
3. Preparation of haemin crystals.
4. Estimation of haemoglobin content
5. Determination of blood groups
6. Measurement of blood pressure using sphygmomanometer
7. Determination of oxygen consumption (cockroach)

8. Preparation of casein from milk
9. Recording of simple muscle twitch with electrical stimulation (or Virtual)
10. Demonstration of reflex action
11. Study of permanent histological sections of mammalian oesophagus, stomach, duodenum, rectum, lung, kidney and brain cells

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
V/ VI	**DSE-6**	**Human Reproductive Biology**	Theory:04 Practical: 02 Total: 06

About the course

The major objective of this course is to provide students with a sound coverage of human reproductive biology within the framework of Human Biology. It also envisages the detailed structure and function of the male and female reproductive tracts, gametogenesis, fertilization, early embryogenesis, foetal development and preparation for birth, and maternal adaptations to pregnancy.

Learning outcomes

Upon successful completion of this course, students should be able to:

- Explain and contrast the processes of spermatogenesis, oogenesis.
- Demonstrate an understanding of the hormonal control of reproduction in males and how this is regulated;
- Distinguish between the main stages of embryonic, foetal and neonatal development and causes of foetal disorders.
- Understand the origin and characteristics of common congenital malformations;
- Know how sexually transmitted diseases may contribute to altered neonatal or reproductive function.
- Critically assess relevant scientific literature in Human Reproductive Biology and present their argument in oral and written work.

<u>Theory</u>

Unit-I: Human Reproductive system **14 Lectures**

Structure and function of male reproduction; Formation of sperm and fertility of individual; Steroids in sports, exogenous and endogenous**.** Structure and function of female reproduction; Sexual differentiation, Puberty; Formation of the gametes; Formation of ova. Physiology of ovulation, menstrual cycle; Nutrition and stress influences on the ovulatory cycle.

Unit-II: Fertilization, foetal development and senescence **12 Lectures**

Process of fertilization; Implantation and formation of the foetus and placenta; Pregnancy, foetal development; Labour and birth, lactation and neonatal life; Reproductive Ageing; Menopause.

Unit-III: Evolution of reproductive mechanism and regulation **12 Lectures**

Evolution of human reproductive strategy; Evolutionary impact on behaviour; Sexuality hormonal effects on maternal-infant bonding; Parturition; Society's effects on reproduction; Stress, anorexia, steroids in the environment; Endocrine disrupting chemicals.

Unit-IV: Reproductive Health **14 Lectures**

Sexual dysfunctions, sexually transmitted diseases; Cancers of the reproductive system; Adenomyosis: gland-like growth into myometrium; Birth Control; Assisted Reproduction Technologies; Intrauterine devices (IUD), endometriosis, fibroids, Endometritis: chronic infection of uterus, congenital uterine anomalies; Ovarian cysts, pelvic varicosities.

Recommended readings

1. Thomas W.S. (2014) Langman's Medical Embryology (13th edition) Lippincott, Williams & Wilkins, Baltimore.
2. Gary C.S.; Steven B.B.; Philip R.B. and Philippa H.F. (2014) Larsen's Human Embryology (5th edition) Elsevier.
3. Gilbert, S.F. (2016) Developmental Biology (11th edition) Sinauer.

<u>Practical</u>

1. Examination of histological sections from photomicrographs/ permanent slides of rat/human: testis, epididymis and accessory glands of male reproductive systems;
2. Sections of ovary, fallopian tube, uterus (proliferative and secretory stages), cervix and vagina.
3. Sperm count and sperm motility in rat
4. Study of modern contraceptive devices

Group discussion or Seminar presentation on one or two related topics from the list (page no.25-28).

Semester	Course	Course Title	Credit
V/ VI	**DSE-7**	**Genetic Engineering and Biotechnology**	Theory:04 Practical: 02 Total: 06

About the course

This course gives an insight into the direct manipulation of DNA to alter the characteristics of an organism in a particular way. It envisages concepts, mechanisms, biological designs, functions and evolutionary significance of genetic modification or manipulation in special organisms and also discusses the recent advance in recombinant DNA technology.

Learning outcomes

After successfully completing this course, the students will be able to:

- Develop an understanding of the fundamental molecular tools and their applications of DNA modification and cloning.
- Appreciate shifting their orientation of learning from a descriptive explanation of biology to a unique style of learning through graphic designs and quantitative parameters to realize how such research and innovations have made science interdisciplinary and applied.
- Develop future course of their career development in higher education and research with a sound base.
- Apply their knowledge with problem solving approach to recommend strategies of genetic engineering for possible applications in Biotechnology and allied industry.

Theory

UNIT I: Scope of genetic engineering **13 Lectures**

Introduction to Genetic Engineering and Biotechnology. Enzymes as Tools for Genetic Engineering: Restriction Enzymes, Restriction-Modification System, DNA-modifying enzymes, T4 and *E. coli* DNA Polymerase (Klenow), DNA-methylase, Polynucleotide Kinase, DNA-ligase, Taq DNA polymerase, Reverse Transcriptase, T7 and T3 RNA polymerases. Vehicles for DNA cloning: Plasmid DNA vectors, bacteriophage lambda-derived vectors.

UNIT II: Recombination and cloning **13 Lectures**

DNA (Gene) cloning, recombinant DNA, cDNA library, genomic library. Isolation of gene from gene library. Screening and identification of recombinant DNA clone from gene library. Expression of recombinant protein from a DNA clone in bacteria and purification of the protein. Some examples of the useful recombinant proteins: Insulin, Streptokinase, enzymes, antibodies, vaccines.

UNIT III: Recent advances in gene technology **13 Lectures**

Polymerase Chain Reaction (PCR) and Site-directed, Restriction enzyme digestion. Transgenic animals, Ligation, Cloning, Transformation, Calculation of transformation efficiency. Mutagenesis. Recent trends in Gene technology. Gene Targeting: Knock-ins and Knock-outs. Targeted Genome Editing: ZFNs, TALENs, CRISPRs etc.

UNIT IV: Genomic studies; ethical issues in genetic engineering **13 Lectures**

DNA Sequencing and Genome Analysis, Model Genomes. Human Genome Project and Human Genome Sequences. Applications of Genetic Engineering and Biotechnology in agriculture, medicine and its economic and social implications, Ethical precautions.

Recommended readings

1. Primrose, S.B. and Twyman, R. (2006) Principles of Gene manipulation and Genomics (7th edition) Blackwell Publishing.
2. Nicholl, D.S.T. (2008) An introduction to Genetic Engineering (3rd edition) Cambridge University Press.
3. Watson, J.D. (2006) Recombinant DNA (3rd edition) Cold Spring Harbor Laboratory Press.

4. Brown, T.A. (2001) Gene Cloning and DNA Analysis: An Introduction.
5. A PBS Documentary entitled, "Playing God" [History of Genetic Engineering]

Practical

1. Video-graphic demonstrations on the above mentioned topics.
2. Models and Presentations by students on the topics: Microbial degradation of waste materials, Antibiotics from microorganisms, Transgenic Tomato and Rice, Recombinant Interferon, Growth Hormone, Insulin, Colony Stimulating Factor, Streptokinase, Industrial Enzymes.
3. Restriction enzyme digestion.
4. Separation of molecules using electrophoresis, Cloning.
5. Transformation, Calculation of transformation efficiency.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
V/ VI	**DSE-8**	**Agrochemicals and Pest Management**	Theory:04 Practical: 02 Total: 06

About the course

The course gives insight into the various types of biological pesticides used to control pest and also about their selective mode of action. It also gives an account of eco-friendly biological pesticides.

Learning outcomes

After successfully completing this course, the students will be able to:

- Gain knowledge and expertise on the agrochemicals and their modes of action and their fates in the agro-ecosystem.
- Have the knowledge of pesticide families and be able to differentiate among families based on their specific modes of activity.
- Aware of the laws and regulations governing the proper use of pesticides.
- Develop appropriate pesticide management strategies by evaluating specific pest type.
- Understand the factors involved in calibrating equipment for pesticide applications.
- Estimate the potential hazards to humans, wildlife, and the environment.

Theory

Unit-I: Concept of pest **13 Lectures**

Definition, classification, morphology and internal systems; Plant pests –weeds, bacteria, fungi, Viruses, nematodes, molluscs, Arthropods, birds, mammals etc.; Causes of outbreak of pest, growth and development; Classification based on nature of damage: Public health pests, Agricultural pests, Domestic pests, Animal husbandry pests, Structural pests

Unit-II: Agrochemicals/ nutrients for increasing the health of plants **13 Lectures**

Manures: types, composition and value, sources of manures, Compost- Different composting technologies-Mechanical compost plants-Vermicomposting-Green manures-Oil cakes, Sewage sludge-Biogas plant slurry. Chemical fertilizers: Classification and value. N-fertilizers: Manufacturing of Ammonium Sulphate, Ammonium Chloride, Ammonium Nitrate and urea; P- fertilizers: sources, processing rock phosphate, bones for bone meal preparation; K- fertilizers: sources, Potassium Chloride, Potassium Sulphate and Potassium Nitrate; Biofertilizers: Classification and value; *viz*., *Rhizobium*, *Azatobactor*, *Azolla*, Blue Green Algae, VAM.

Unit-III: Agrochemicals for pest management **13 Lectures**

Coventional chemicals/ pesticides based on target species: Acaricides, Fungicides, Rodenticides, Nematicides, Molluscicides, Fumigants and Repellents; Based on chemical nature: Organophosphates; Organochlorines, Carbamates etc.; Structure, chemical name, physical and chemical properties; Degradation metabolism, Mode of action, uses, toxicity; Application of Pesticides, devices used; dose estimation for field application.

Unit-IV: Botanicals and other biopesticides **13 Lectures**

Potential pesticidal plants; Plant extracts and Bio-organisms: Azadirachtin and its role in pest control; Other biopesticides: Pyrethrins, Pyrethroids, Rotenone, Nicotine and Nicotinoids. Growth inhibitors or physiological antagonists, chemo-sterilants; pheromones and attractants; Insect growth regulators, juvenile hormones, moulting hormones; Chitin synthesis inhibitors. Moulting Inhibitors. BT methodology, genetically modified and transgenic plants.

Recommended readings

1. Hill, D.S. (1983) Agricultural insect pests of the tropics and their control- Cambridge Univ. Press.
2. Atwal, A. S. (1979) Agricultural pests of India and south East Asia.
3. Dent, D. (2000) Insect pest management (2nd edition) CAB International.
4. Roberts, D.A. (1978) Fundamentals of Plant Pest Control.

5. De Bach, P. (1964) Biological Control of Insect Pests and Weeds, Chapman & Hall, New York.
6. Koul, O. and Dhaliwal, G.S. (2003) Phytochemical Biopesticides, Harwood Academic Publishers, Amsterdam.
7. Pedigo, L.P. (1996) Entomology and pest management, Prentice Hall, N. Delhi.

Practical

1. Identification of common natural enemies of crop pests (parasitoids, predators, microbes).

2. Study the damage caused by the commonly occurring insect pests – Infected plant/plant parts.

3. Preparation of Neem and *Lantana Camara* based botanical pesticides.

4. Field trips to bio-control laboratories – IARI, CWC, FCI.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
V/ VI	**DSE-9**	**Wildlife Conservation and Management**	Theory:04 Practical: 02 Total: 06

About the course

The course is an introduction to wildlife management and gives an account of the tools used by wildlife managers. Topics covered are to equip students with adequate knowledge of various biodiversity monitoring methodologies, conservation and management issues of vertebrate pests, wildlife conflict and over abundant species, wildlife health and diseases.

Learning outcomes

After successfully completing this course, the students will be able to:

- Develop an understanding of how animals interact with each other and their natural environment
- Develop the ability to use the fundamental principles of wildlife ecology to solve local, regional and national conservation and management issues
- Develop the ability to work collaboratively on team-based projects
- Demonstrate proficiency in the writing, speaking, and critical thinking skills needed to become a wildlife technician
- Gain an appreciation for the modern scope of scientific inquiry in the field of wildlife conservation management
- Develop an ability to analyze, present and interpret wildlife conservation management information.

<u>Theory</u>

Unit-I: Value of wildlife and need for its conservation **13 Lectures**

Definition, value and importance of wildlife; Types of ecosystems. Causes of depletion of wildlife; Inventory and classification of wetland and animal inhabitants;Population vulnerability analysis and its components; Factors responsible for the extinction of animals; Types of protected areas and the concept of zoning within the protected areas; Wildlife Sanctuaries and National Parks in India: general strategies and issues; Theories of population dispersal; Animal movement, concept of home range and territory; Tracking movement by remote sensing and GIS.

Unit-II: Population and prey-predator dynamics **13 Lectures**

Wildlife conservation, ethics and importance of conservation; Impact of topography, geology, soil and water on wildlife; Impact of habitat destruction and fragmentation on wildlife; Biological parameters such as food, cover, forage and their impact on wild life; Population attributes; concepts of exponential and logistic growth rates of wildlife; Density dependent and independent population regulation; Impact of introduced species on preexisting flora and fauna of wildlife; Identification and estimation of wild animals by fecal sample analysis, hair identification, pug marks and census methods. Predator-prey models and impact of predation.

Unit-III: Wildlife Conservation **13 Lectures**

Wildlife conservation objectives- strategies and issues; Captive breeding techniques and translocation and reintroduction; Inviolate area and critical habitats and their impact on wildlife; Different terrestrial habitats of wildlife in India; Restoration of degraded habitat; Damage caused by wildlife in India and its mitigation; Sick animal refuges in protected areas.

Unit-IV: Rehabilitation and management **13 Lectures**

Type of wildlife management-manipulative, custodial; Management of over abundant wild animal populations causing damages to nearby inhabitants and their crops and animals; Tools and techniques to control the menace of wild animals; man wildlife conflict resolution and mitigation; Management of exotic and invasive wetland species in India. Habitat manipulation– control and regulation of grazing. Weed eradication; Major diseases of domestic and wild animals and their control and impact of wild life tourism.

Recommended readings

1. Caughley, G., and Sinclair, A.R.E. (1994) Wildlife Ecology and Management. Blackwell Science.
2. Woodroffe, R., Thirgood, S. and Rabinowitz, A. (2005) People and Wildlife, Conflict or Co-existence? Cambridge University.
3. Bookhout, T.A. (1996) Research and Management Techniques for Wildlife and Habitats (5th edition) The Wildlife Society, Allen Press.
4. Sutherland, W.J. (2000) The Conservation Handbook: Research, Management and Policy. Blackwell Sciences
5. Hunter M.L., Gibbs, J.B. and Sterling, E.J. (2008) Problem solving in Conservation Biology and Wildlife Management: Exercises for Class, Field, and Laboratory. Blackwell Publishing.

Practical

1. Identification of flora, mammalian fauna, avian fauna, herpeto-fauna.
2. Demonstration of basic equipment needed in wildlife studies use, care and maintenance (Compass, Binoculars, Spotting scope, Range Finders, Global Positioning System, Various types of Cameras and lenses).
3. Familiarization and study of animal evidences in the field; Identification of animals through pug marks, hoof marks, scats, pellet groups, nest, antlers etc.
4. Demonstration of different field techniques for flora and fauna.
5. Trail / transect monitoring for abundance and diversity estimation of mammals and bird (direct and indirect evidences).

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
V/ VI	**DSE-10**	**Aquatic Biology**	Theory:04 Practical: 02 Total: 06

About the course

The program of study aims to provide students with a broad-based foundation in science together with extensive subject knowledge in the discipline of aquatic biology. It also aims to develop a range of transferable research, analytical and communication skills.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand and apply relevant scientific principles in the area of aquatic biology
- Employ scientific methodologies such as experimentation and data analysis in the area of aquatic biology
- Critically analyse, interpret and evaluate information relevant to aquatic biology
- Appreciate the multidisciplinary nature of the study of aquatic biology and engage positively with people and ideas beyond their own discipline.
- Explore some of the unique environmental problems dealing with aquatic environments.
- Develop *employable skills* in freshwater biological water quality analysis.

UNIT – I Abiotic conditions of Freshwater ecosystems **14 Lectures**

Physical Properties of Water; chemical properties of water; Brief introduction of the aquatic ecosystems. Freshwater ecosystems (lakes, wetlands, streams and rivers). Physico-chemical Characteristics of fresh water bodies: Light, Temperature, Thermal stratification, Dissolved

Solids, Carbonate, Bicarbonates, Phosphates and Nitrates, Turbidity: dissolved gases (Oxygen, Carbon dioxide). Origin and classification of lakes; Streams: Different stages of stream development.

UNIT II Aquatic organisms **10 Lectures**

Feeding in aquatic organisms; respiration in aquatic organisms; osmoregulation in freshwater and marine organisms; sensory world of aquatic organisms; Locomotion in water. Adaptation of hill-stream fishes. Adaptation of deep sea organisms.

UNIT – II Abiotic conditions of marine ecosystems **14 Lectures**

Classification of marine ecosystem: Estuaries, intertidal zones, Oceanic pelagic zone, marine benthic zone. Coral reefs. Physico-chemical environment, Salinity and density of sea water and Continental shelf; other factors *viz*., Light, Temperature, Thermal stratification, Dissolved Solids, Turbidity: dissolved gases (Oxygen, Carbon dioxide).

UNIT – III Management of Aquatic Resources **14 Lectures**

Aquatic pollution - Causes of pollution: Agricultural, Industrial, Sewage, Thermal and Oil spills, Eutrophication, Management and conservation. Water pollution acts of India. Sewage treatment and water quality assessment - BOD and COD.

Recommended readings

1. Goldman, C. (1994) Limnology (2nd edition).
2. Ananthakrishnan, T.N. (1989) Bioresources Ecology (3rd edition).
3. Odum, E.P. and Barrett, G.W. (2004) Fundamentals of Ecology (5th edition).
4. Pawlowski, L. (1980) Physicochemical Methods for water and Wastewater Treatment.
5. Wetzel, R. (2001) Limnology (3rd edition) Elsevier.
6. Trivedy, R.K. and Goyal, P.K. (1986) Chemical and biological methods for water pollution studies.
7. Welch, P.S. (2014) Limnology Vol. I-II.

Practical

1. Study of the topography of a lake.
2. Physico-Chemical and biological analysis of a lake.

3. Physico-Chemical analysis of water - O_2, CO_2, BOD, COD.

Biological– Zooplanktons – Identification and population density of Zooplanktons of a lake.

3. Determination of Turbidity / transparency, Dissolved Oxygen, Free Carbon dioxide, Alkalinity (carbonates & bicarbonates) in water collected from a nearby lake / water body.

4. Instruments used in limnology (Secchi disc, van Dorn bottle, conductivity meter, Turbidity meter) and their significance.

5. Identification of Zooplankton- Copepods, Hydromedusae, Pteropods, Chaetognatha etc.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28)

Semester	Course	Course Title	Credit
V/ VI	**DSE-11**	**Live stock management and Animal Husbandry**	Theory:04 Practical: 02 Total: 06

About the course

The course provides intensive study in livestock production, management, marketing, nutrition, breeding, production records, selection, animal health, waste management, and conservation practices.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand skills and requirements necessary to find and maintain a job.
- Select and develop a breeding system for a livestock enterprise.
- Understand the importance of genetic improvement in animal production.
- Formulate feed rations for different classes of livestock.
- Identify common problems associated with livestock and horse herd health and solutions.
- Identify current and future issues relating to animal husbandry.
- Understand different marketing opportunities available for livestock production.

Unit I: Animal products and breeding systems **13 Lectures**

Scope of Livestock Industry; Livestock Enterprises; Issues in Animal Agriculture. Animal Products: Importance of Animal Products; Beef; Pork; Lamb; Poultry Products. Advanced Reproduction and Breeding: Reproductive Systems, Common Breeding Systems including cattle Breeding, Swine, Sheep and Goat Breeding, Hormones and Cycles and effect of environment. Reproductive Technologies.

Unit II: Animal products and breeding systems **13 Lectures**

Nutritional requirements: Energy requirements for maintenance, growth, milk, egg, wool, and meat production. Carbohydrates & Fats, Protein, Minerals & Vitamins, Water etc. Common Feedstuffs Systems for expressing energy value of foods in ruminants, pigs and poultry. Direct and indirect calorimetry. Advanced Ration Formulations .

Unit III: Maintenance of breeds **13 Lectures**

Common Breeds of Livestock: Breeds of Cattle, swine, sheep, goat and poultry: Selecting live stocks; Facilities and Equipment; Housing, Maintenance and health care; Management of breeding stocks and products. Vaccination programmes and Deworming programmes.

Unit IV: Marketing and related issues **13 Lectures**

Planning and Marketing; Culling, Forward Contracting, Backgrounding. Quality control; Future prospects. Basic principles of Genetics and tools for genetic improvement. Current issues affecting the livestock industry.

Recommended readings

1. Taylor, R.E and Field, T.G. (2004).Scientific Farm Animal Production: An Induction to Animal Science. Prentice-Hall
2. Acker, D. and Cunningham, M. (1998). Animal Science & Industry. Prentice-Hall.
3. Blakely, J. and Bade, D. (1985). The Science of Animal Husbandry. Prentice-Hall.
4. Cambell, J. and Lasley, J. (1975).The Science of Animals that Serve Mankind. McGraw-Hill.
5. Cooper, E. L. (1990). Agriscience: Fundamentals & Applications Delmer: Albany.
6. American Youth Horse Council (1999) Handbook: A Guide to Equine Care and Management.
7. Morrison, F. (1949). Feeds and Feeding (8th edition) Morrison: Ithaca.

Practical

1. Estimation of amino acids, proteins and fatty acids in feed.
2. Virtual demonstration of endocrine glands and their influence on growth of live stock.
3. Estimation of albumen and yolk quantity in eggs.
4. Estimation of calcium in egg shell.
5. Estimation of cholesterol and peroxides in meat.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

General Elective Courses

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-1**	**Exploring the Brain: Structure and Function**	Theory:04 Practical: 02 Total: 06

About the course

The course provides an insight into the structure of brain, its associated functions, its gradual evolution with increased cranial capacity, mechanism of neurotransmission and the associated neurodegenerative disorders.

Learning outcomes

After successfully completing this course, the students will be able to understand:

- The early and current status of neuroscience.
- The structure of brain cells and their circuit.
- Evolution and adaptation of brain.
- Brain development, aging and imaging.
- Neurotransmitters and their action.
- The process of learning and memory.
- Different type of brain disorders.

Theory

UNIT I: Scope of Neuroscience. Brain structure **11 Lectures**

Introduction to Neuroscience and its scope**.** Early and 19th century views of the Brain. Latest advances in Neuroscience today. Brain cells, types: Neurons – types and structure; Glia- types and structure; Neuronal circuit.

UNIT II: Evolution and development of brain **12 Lectures**

Evolution and Adaptation of Brain: Theories of brain evolution. Evolution of brain in vertebrates and associated behavioral adaptation. Organization and development of brain in human. Divisions of the brain. Structure-function relationship. Neuroimaging- CT and MRI.

UNIT III: Neurotransmitters and mechanism of neurotransmission **13 Lectures**

Neurotransmitters and neurotransmission: Noradrenergic, serotonergic, dopaminergic and cholinergic system. Mechanism of neurotransmission and drug action. Learning and memory. Types, mechanism, disorders.

UNIT IV: Managing brain health **16 Lectures**

Brain aging: Structural and chemical changes. Functional changes. Maintenance of healthy brain. Brain disorders: Neurodegenerative diseases- Epilepsy, Stroke, Alzheimer’s, Parkinsons. Neuropsychiatric disorders- Anxiety, Depression, Mood disorders, Schizophrenia.

Recommended readings

1. Squire, L. *et al.* (2003) Fundamental Neuroscience, Academic Press.

2. Kandel, E. (2000) Principles of Neural Science, McGraw Hill

Practical

1. Dissection and study of *Drosophila* nervous system using GFP reporter.
2. Observation and quantization of *Drosophila* photoreceptor neurons in healthy and diseased conditions.
3. Experiments based on the course contents.
4. Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-2**	**Human Physiology**	Theory:04 Practical: 02 Total: 06

About the course

The course provides an insight into the structure and function of organ systems in humans and their involvement in body metabolism towards maintenance of homeostasis.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand the process of digestion and its control
- Develop understanding in muscle structure and contraction mechanism
- Learn the process of respiration and transport of gases
- Understand kidney structure and regulation of urine formation
- Understand heart structure and functioning
- Understand function of endocrine glands and formation of gametes.

Theory

UNIT I: How are processes of digestion and excretion accomplished in man ?

13 Lectures

Digestive glands: Structure and function. Digestion and absorption of nutrients: carbohydrates, fats and proteins. Neural and hormonal control of digestion. Excretory system: Functional anatomy of kidney. Mechanism of excretion and regulation of urine formation.

UNIT II: An overview of muscular function and respiration in man **13 Lectures**

Structure of smooth, skeletal and cardiac muscles. Neuromuscular junction. Mechanism of muscle contraction. Respiration: Ventilation, External and internal respiration. Transport of carbon dioxide and oxygen in blood and tissues. Factors affecting gaseous transport.

UNIT III: Cardiovascular functions in man **10 Lectures**

Structure of heart. Coordination of heartbeat; control of heart beat (neural and hormonal) Blood cells and blood vessels. Cardiac cycle. ECG. Lymph and lymph vessels.

UNIT IV: Endocrine and reproductive physiology **16 Lectures**

Structure and function of endocrine glands *viz*., pituitary, thyroid, parathyroid, pancreas, adrenal, ovaries and testes. Processes of spermatogenesis and oogenesis. Fertilization and implantation. Menstrual cycle. Pregnancy and Parturition.

Recommended readings

1. Tortora, G.J. and Derrickson, B.H. (2009) Principles of Anatomy and Physiology (12th edition) John Wiley and Sons, Inc.
2. Widmaier, E.P., Raff, H. and Strang, K.T. (2008) Vander's Human Physiology (9th edition) McGraw Hill.
3. Guyton, A.C. and Hall, J.E. (2011) Textbook of Medical Physiology (12th edition) Harcourt Asia Pvt. Ltd/ W.B. Saunders Company.
4. Marieb, E. (1998) Human Anatomy and Physiology (4th edition) Addison-Wesley.
5. Kesar, S. and Vashisht, N. (2007) Experimental Physiology, Heritage Publishers.

Practical

1. Temporary mount reparation of Neurons and Blood film.
2. Preparation of haemin and haemochromogen crystals.
3. Haemoglobin estimation using Sahli's haemoglobinometer.
4. Study of permanent histological sections of mammalian oesophagus, stomach, duodenum, rectum, lung, adrenal, kidney, thyroid, pancreas, testis, ovary.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-3**	**Vectors, Diseases and Management**	Theory:04 Practical: 02 Total: 06

About the course

The course provides an insight into the common vector-borne diseases, their etiology, role of vectors in their spread, host- parasite relationship and finally the strategies to manage these vectors.

Learning outcomes

After successfully completing this course, the students will be able to:

- Develop awareness about the causative agents and control measures of many commonly occurring diseases.
- Develop understanding about the favourable breeding conditions for the vectors.
- Devise strategies to manage the vectors population below threshold levels, public health importance.
- Undertake measures or start awareness programmes for maintenance of hygienic conditions, avoidance of contact from vector, destruction of breeding spots in the vicinity of houses and cattle shed by public health education campaign.

Theory

Unit I: Vector and vector bionomics **13 Lectures**

Brief introduction, types and morphological peculiarities of vectors such as mosquitoes, flies, fleas, lice, bugs, ticks and mites. Host-vector relationship. Primary and secondary vector concept. Vectorial capacity. Vector bionomics-larval habitats and host biting preferences, human and animal biting indices. Evolution of vector bionomics and its effect on disease transmission. Vector incrimination. Human practices and the occurrence of pests

Unit II: Disease vectors and the causes of disease outbreaks **13 Lectures**

Salient features of the vectors belonging to Diptera, Siphonaptera, Siphunculata, Hemiptera, Arachnida, Blattaria, Acarina (families Ixodidae and Argasidae) etc. Role of non-blood sucking flies in myiasis; of blood sucking flies in transmission of plague and typhus; of lice (body, head, pubic) in transmission of typhus, relapsing and trench fevers, Vagabond's disease and Phthiriasis; of bugs in transmission of Chaga's disease of. Brief account of mites and the associated diseases. Population biology, Factors affecting abundance, Density dependence and independence, How do people cause outbreak?

Unit III: Vector management strategies **13 Lectures**

Control of vector flies by screening, fly traps, electrocution, poison baits and outdoor residual sprays; biological control by natural parasites and predators. Chemical control. Efficacy of synthetic pyrethroids, residual spray of insecticides, treated bed nets/curtains and fumigations. Biological control of mosquitoes by the use of viruses, bacteria, fungi, parasites, nematodes and larvivorous fishes. Sterile insect technique, Eradication, Other genetic approaches, Pheromones/allelochemicals, Attract-and –kill, Mating disruptors, alarm pheromones and oviposition disruptors

Unit IV: Emerging concepts and approaches to vector management **13 Lectures**

Legislation and regulation, Methods of sampling and monitoring, sampling plan, Allocation of sampling units. Exclusion and routes of entry. Controlled atmosphere, Risk assessment, The integrated control/ IPM approach, Damage thresholds estimation, Forecasting, Increasing agroecosystem resistance, Pesticide selection, Eradication versus control, Up to what limits IPM should be adopted. Decision support

Recommended readings

1. Imms, A.D. (1977). A General Text Book of Entomology. Chapman & Hall, UK.
2. Chapman, R.F. (1998). The Insects: Structure and Function.IV Edition, Cambridge University Press, UK.

3. Mathews, G. (2011). Integrated Vector Management: Controlling Vectors of Malaria and other Insect Vector borne Diseass.Wiley-Blackwell.
4. Belding, D.L. (1942). Textbook of Clinical Parasitology. Appleton-Century Co., Inc., New York.
5. Roy, D.N. and Brown, A.W.A. (2004). Entomology. Biotech Books, Delhi

Practical

1. Study of mouth parts of different insects.
2. Study of permanent slides of the following insect vectors: *Aedes*, *Culex*, *Anopheles*, *Pediculus humanus corporis*, *Pediculus humanus capitis*, *Phthirus pubis*, *Xenopsylla cheopis*, , *Musca domestica*, *Cimex lectularius*, *Phlebotomus argentipes* through permanent slides/ videos.
3. State the diseases transmitted by above insect vectors.
4. Project report submission on any one of the insect vectors and the disease transmitted.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28)

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-4**	**Food, Nutrition and Health**	Theory:04 Practical: 02 Total: 06

About the course

The course covers the basic concepts of balanced diet for people of different ages besides focusing on the consequences of malnutrition and the deficiency diseases and the diseases caused due to poor hygiene.

Learning outcomes

After successfully completing this course, the students will be able to:

- Understand the role of food and nutrients in health and disease.

- Provide culturally competent nutrition services for diverse individuals.
- Implement strategies for food access, procurement, preparation, and safety that are relevant for the culture, age, literacy level, and socio-economic status of clients and groups.
- Perform food system management and leadership functions that consider sustainability in business, healthcare, community, and institutional arenas.

<u>Theory</u>

Unit 1: Nutrition and dietary nutrients — 12 Lectures

Basic concept of Food: Components and nutrients. Concept of balanced diet, nutrient requirements and dietary pattern for different groups viz., adults, pregnant and nursing mothers, infants, school children, adolescents and elderly people.

Unit II: Macro nutrients and micronutrients **12 Lectures**

Nutritional Biochemistry: Macronutrients. Carbohydrates, Lipids, Proteins- Definition, Classification, their dietary source and role. Micronutrients. Vitamins- Water-soluble and Fat-soluble vitamins- their sources and importance. Important minerals *viz*., Iron, Calcium, Phosphorus, Iodine, Selenium and Zinc: their biological functions.

Unit III: Malnutrition and nutrient deficiency diseases **15 Lectures**

Definition and concept of health: Common nutritional deficiency diseases- Protein Malnutrition (e.g., Kwashiorkor and Marasmus), Vitamin A deficiency, Iron deficiency and Iodine deficiency disorders- their symptoms, treatment, prevention and government initiatives, if any. Life style dependent diseases- hypertension, diabetes mellitus, and obesity- their causes and prevention. Social health problems- smoking, alcoholism, narcotics. Acquired Immuno Deficiency Syndrome (AIDS): causes, treatment and prevention. Other ailments *viz*., cold, cough, and fever, their causes and treatment.

Unit IV: Diseases caused by microorganisms **13 Lectures**

Food hygiene: Potable water- sources and methods of purification at domestic level. Food and Water-borne infections: Bacterial diseases: cholera, dysentery; typhoid fever, viral diseases: Hepatitis, Poliomyelitis etc., Protozoan diseases: amoebiasis, giardiasis; Parasitic diseases: taeniasis and ascariasis their transmission, causative agent, sources of infection, symptoms and prevention. Causes of food spoilage and its prevention.

Recommended reading

1. Mudambi, S.R. and Rajagopal, M.V. (2007). Fundamentals of Foods, Nutrition and Diet Therapy; Fifth Ed;; New Age International Publishers
2. Srilakshmi, B. (2002). Nutrition Science; New Age International (P) Ltd.
3. Srilakshmi, B. (2007). Food Science; Fourth Ed; New Age International (P) Ltd.
4. Swaminathan, M. (1986). Handbook of Foods and Nutrition; Fifth Ed; BAPPCO.
5. Bamji, M.S.; Rao, N.P. and Reddy, V. (2009). Text Book of Human Nutrition; Oxford & IBH Publishing Co. Pvt Ltd.
6. Wardlaw, G.M. and Hampl, J.S. (2007). Perspectives in Nutrition; Seventh Ed; McGraw Hill.
7. Lakra, P. and Singh M.D. (2008). Textbook of Nutrition and Health; First Ed; Academic Excellence.
8. Manay, M.S. and Shadaksharaswamy, M. (1998). Food-Facts and Principles; New AgeInternational (P) Ltd.

9. Gibney, M.J. et al. (2004). Public Health Nutrition; Blackwell Publishing.

Practical

1. Datecting adulteration in a) Ghee b) Sugars c) Tea leaves and d) Turmeric.

3. Estimation of Lactose in milk.

4. Titrimetric method for Ascorbic acid estimation .

5. Estimation of Calcium in foods by titrimetry.

6. Study of the stored grain pests from slides/ photograph(Sitophilus oryzae, *Trogoderma granarium*, *Callosobruchus chinensis* and *Tribolium castaneum*): their identification, habitat and food sources, damage caused and control. Preparation of temporary mounts of the above stored grain pests.

7. Project- Computer aided diet analysis and nutrition counselling for different age groups.

8. Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-5**	**Global Climate change**	Theory:04 Practical: 02 Total: 06

About the course

This course provides an overview of the Earth's climate system, the various forcing and feedbacks controlling the Earth's climate variability in short and long timescale. It will give a brief introduction to the atmosphere and ocean circulation.

Learning outcomes

After completing this course, the student will be able to:

- Develop understanding on the concept and issues of global environmental change.
- Analyse the causes and effects of depletion of stratospheric ozone layer.
- Examine the climate change and its effect on living beings.
- Understand the physical basis of natural green gashouse effect on man and materials.
- Evaluate human influenced driver of our climate system and its applications.

Theory

Unit I: An overview of earth system **13 lectures**

Global Environmental change issues. Paleoclimate – what can we learn from the past? Concept of earth system, climate forcing, responses, feedback loops, equilibrium states, Daisy world model, Solar Flux at Earth's Orbit, Stratospheric ozone layer: Evolution of ozone layer; Planetary Energy balance, seasonal variability. Radiative transfer, an improved estimate of climate sensitivity.

Unit II: Causes and consequences of Ozone layer depletion **12 lectures**

Greenhouse gases and their sources; Greenhouse effects; Causes of depletion of ozone layer and consequences; Climate change: Effects of enhanced UV-B on plants, microbes, animals, human health and materials; global energy infrastructure and GHG emissions.

Unit III: Other adverse impacts on climate **14 lectures**

Atmospheric deposition: Past and present scenario; Causes and consequences of excessive atmospheric deposition of nutrients and trace elements; Acid rain and its effects on plants, animals, microbes and ecosystems. Eutrophication, Consequences on climate, oceans, agriculture, natural vegetation and humans; Clouds, Storms and Climate -Cloud Formation and Climate, El Niño and the Southern Oscillation -El Niño and its Effects.

Unit IV: International summits and agreements **13 lectures**

International efforts on climate change issues. Global efforts for mitigating ozone layer depletion. Climate modeling and climate change feedbacks. International Agreements: the United Nations Framework Convention on Climate Change, Kyoto Protocol, Paris Agreement. Integrated Assessment, Decisions under uncertainty: Abate now, or delay? Emissions budgets.

Recommended readings

1. Adger, N.; Brown, K. and Conway, D. (2012). Global Environmental Change: Understanding the Human Dimensions. The National Academic Press.
2. Turekian, K.K. (1996). Global Environmental Change-Past, Present, and Future. Prentice-Hall.
3. Matthew, R.A.; Barnett, J. and McDonald, B. (2009). Global Environmental Change and Human Security. MIT Press., USA.
4. Hester, R.E. and Harrison, R.M. (2002). Global Environmental Change. Royal Society of Chemistry.

Practical

There are no structured class lab experiments involved. However, the students are expected to visit various sites on the web, make teams for group-discussion indulge in debates, collect justifiable information from various sources, make historical report on the science, impact, future and politics behind climate change.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28)

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-6**	**Environmental Microbiology**	Theory:04 Practical: 02 Total: 06

About the course

The course provides an insight into the immense importance of the microbes around us. Their uses and benefits outweigh their harmful aspects. It focuses on the role of microbes in waste management and environmental restoration.

Learning outcomes

After successfully completing this course, the students will be able to:

- Develop understanding on the microbiology diversity, processes and applications in the environment.
- Analyze the contribution of microbiology area of science in water treatment, solid waste management, bioremediation and phytoremediation.
- Evaluate the implications of mass cultivation, inoculums preparation, quality control, and vermicomposting
- Apply the skills for environmental protection

Theory

Unit I: Microbiology and the microbes 12 Lectures

Introduction to environmental microbiology; History and scope, cultivation of microbial communities, importance and significance of community culture. Methods for detection of community cultures, culturable microorganisms, phylogenetic and molecular profiling of microbes in the environment

Unit II: Bioremediation of waste water **13 Lectures**

Water microbiology: waste water treatment, method, aerobic and anaerobic processes, solid waste management, landfills, containment types, composting and applications; Bioremediation, bio-filters, microbial polymers, microbial plastics, Bioaccumulation, Biomagnification, marine pollution, concepts and remediation strategies.

Unit III: Microbes in air and water **15 Lectures**

Aeromicrobiology: Intramural and extramural aero-microbiology, Aerosols and Bioaerosols: Sources and launching, Diversity and Survival of microbes in air, control, Aeroallergens, Pollen allergy, Hypersensitivity, effect of climate change on pollen and spore discharge. aquatic microbiology: aquatic environment; fresh, brackish and marine waters and their microbiology, hydrothermal vents, hot spring, Arctic and Antarctic environment. Soil Microbiology: Soil formation, sampling of soil and deep subsurface soil, rhizospheric and agricultural soil; microbes of surface and subsurface soil. Environmentally stressed soil.

Unit IV: Nutrient recycling and manuring **12 Lectures**

Biogeochemical cycling: Carbon, Nitrogen, Phosphorus and Sulphur; Importance. Biofertilizers: Definition, types, mass cultivation, inoculums preparation, quality control, significance and applications. Vermicomposting.

Recommended readings

1. Sharma, P. D. (2005). Environmental Microbiology. Alpha Science International Ltd. ISBN. 1842652761
2. Bertrand, J. C., Caumetter, P., Laboron, R., Matheron, R., Normand, P., SIme-Nganda. (2015). Environmental Microbiology: Fundamental and Applications of Microbial Ecology. Editor: Springer
3. Pepper, I.; Gerba, C. and Gentry, T. (2014). Environmental Microbiology Academic Press.
4. Pradipta, K. and Mohapatra, I. K. (2008). Text book of Environmental Microbiology.

Practical

The goal of the practical is to get acquainted with the microbiological laboratory techniques of environmental analysis.

1. Monitoring of pollution indicating microbe communities in case of hydrocarbon-polluted soil/groundwater systems.
2. Application of respirometric methods to assess the speed of degradation processes.

3. Assembly of a composting model system, analysis of basic thermal etc. properties.
4. Visit at a composting plant and remediation site.
5. Visit to some nearby forests to collect soil and isolate a variety of microbes.
6. Process of cleaning and disinfecting of the glassware/ plasticware.
7. Preparation of vermicompost.
8. Preparation of culture media for studying bacterial growth.
9. Preparation of Biofertilizer.
10. Measurement of Microbial growth - cell number, cell mass and cell constituent.
11. Study impact of environmental conditions on microbial growth.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28)

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-7**	**Environmental Biotechnology**	Theory:04 Practical: 02 Total: 06

About the course

This course will provide details about the environmental problems, interaction of microbes with animals, microbial diseases, xenobiotic compounds, and role of enzymes in degradation of toxic compounds.

Learning outcomes:

On the completion of the course, the students shall be able to

- Understand different causes of environmental pollution and their remedies
- Analyze microbiology of waste water and its implications
- Examine the role of immobilized cells/enzymes in treatment of toxic compounds
- Reflect upon various sustainable environmental protection strategies
- Evaluate the implications of international legislations, policies for environmental protection

Theory

Unit-I: Environmental Problems **13 Lectures**

Basic concepts and issues, global environmental problems - ozone depletion, UV-B, greenhouse effect and acid rain due to anthropogenic activities and their impacts. Environmental pollution: types and sources of pollution, levels of pollutants, fate of pollutants in the environment, Bioconcentration, bio/geomagnification.

Unit-II: Types of interaction with microbes **13 Lectures**

Types of interaction between animals and microbes, Microbes and public health: Brief account of microbial diseases in humans (water and air borne disease). Microbiology of water: Aerobic process - activated sludge, oxidation ponds, trickling filter, towers, rotating discs, rotating drums, oxidation ditch. Anaerobic process - anaerobic digestion, anaerobic filters. Treatment schemes for waste-waters of dairy, distillery, tannery, sugar and antibiotic industries.

Unit-III: Xenobiotic compounds and microbial remediation **13 Lectures**

Xenobiotic compounds: Organic compounds (Chlorinated hydrocarbons, Polyaromatic hydrocarbons, Pesticides, Surfactants etc.) and inorganic compounds (metals, radionuclides, phosphates, nitrates etc.). Xenobiotic bioremediation: decay behaviour and degradative plasmids, molecular techniques used in bioremediation.

Unit-IV: Environmental Awareness and Management **13 Lectures**

Biopesticides, bioreactors, bioleaching, biomining, biosensors, biotechniques for air pollution abatement and odour control. Economic growth, Gross National Productivity and the quality of life. Tragedy of Commons, Pollution control Economics, Cost-benefit and cost effectiveness analysis, WTO and Environment, Environmental Education and awareness programmes; Environmental Ethics. Regulation of the safety of biotechnology procedure and products: Deliberate release and fate of genetically modified microorganisms.

Recommended readings

1. Metcalf and Eddy Inc. (1978) Waste engineering - treatment, disposal and reuse (2nd edition) Tata McGraw Hill, New Delhi.
2. Baaker, K.H. and Herson, D.S. (1994) Bioremediation, Mc.GrawHill Inc, NewYork.
3. Ahmed, N.;. Qureshi, F.M. and. Khan, O.Y. (2006). Industrial and Environmental Biotechnology - Horizon Press.
4. Rochelle, P.A. (2001).Environmental Molecular Biology, Horizon Press.
5. Pepper I.; Gerba, C.; Gentry, T. and Maier, R. (2008) Environmental Microbiology. Academic Press.

Practical

1. Soil/ Water analysis - pH,DO, salinity, chloride, hardness, alkalinity, acidity, dissolved substances viz., nitrate, calcium, magnesium and phosphorus.
2. Gravimetric estimation-Total solid, dissolved solid, suspended solid in an effluent
3. Microbial studt of air (open plate and air sample) and water
4. Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-8**	**Biodiversity Conservation and Sustainable Development**	Theory:04 Practical: 02 Total: 06

About the course

The course provides information regarding the status of environment, the depletion of its resources, the loss of biodiversity and the remedial efforts undertaken by various agencies. The course is also focused to creating environmental awareness among learners.

Learning outcomes

After successfully completing this course, the students will be able to:

- Develop understanding for the environment which is largely degraded in the current scenario.
- Understand the importance of bio diversity and the consequences of bio diversity loss
- Learn about the judicious utilisation of natural resources
- Follow the concept of green technology and the eco-friendly practises and other prospects of environment protection
- understand and practice appropriate legal/regulatory and ethical issues in the context of the work environment.
- design research projects to collect information to assess the effectiveness of current practices, and interpret the results of a statistical analysis of data, and use this to make informed decisions.

Theory

Unit I: Anthropogenic impact on environment **13 Lectures**

Man as an animal species in the ecosystem. Population explosion. carrying capacity, exploitation of resources due to urbanization, industrialization and agricultural practises. Generation of agricultural, municipal, industrial waste; Pollution of air, water, soil and noise; radioactive pollution. Eutrophication. Deforestation; Threats to biodiversity, Extinction of species.

Unit II: Depletion and contamination of resources **10 Lectures**

Natural resources: Land resources. Air and water resources. Bioresources. Conventional Fuel, wood, fossil fuels. Non-conventional or alternate sources of energy: sun, wind, bio-energy, geothermal, ocean, nuclear etc. Green house effect and global warming; climate change; Shrinking of glaciers. Threats to sustainable development.

Unit III: Biodiversity and resource conservation programmes **14 Lectures**

Management of wastes and disposal. Concepts of three Rs: reduce, reuse and recycle. Methods of prevention and control of Eutrophication. Bioremediation. Biodiversity conservation– In-situ e.g., Sanctuaries, National Parks, Biosphere Reserves, World Heritage Sites; Ex-situ e.g., botanical gardens, gene banks, cryopreservation etc. Contour farming, reforestation; Rainwater harvesting, groundwater water recharge. Green technologies, Eco-cities, Social and Joint forestry.

Unit IV: Sustainable development and green technology **15 Lectures**

Sustainable Development; Brundlandt Report. Biosafety of GMOs and LMOs. Environmental movements. Public awareness of Environment problems. Role of Government, NGO's, Ecological footprint, International treaties and conventions. organizations, International efforts (Vienna Convention, Montreal Protocol, UNFCCC, Kyoto Protocol, Copenhagen Summit, etc.; IPCC; Environmental laws and acts. National Environmental Policy. NBPGR, BSI, ZSI, WWF, IUCN, Convention on Biological diversity; Ramsar Convention, other conservation efforts.

Recommended readings

1. Joseph, B. (2008) Environmental studies, Tata McGraw Hill.
2. Miller, G.T. (2002). Sustaining the earth, an integrated approach. (5th edition) Books/Cole, Thompson Learning, Inc.
3. Chapman, J.L. and Reiss, M.J. (1999). Ecology: Principles and applications (2nd edition) Cambridge University Press.
4. Ghosh, S.K. and Singh, R. (2003). Social forestry and Forest Management. Global Vision Pub.
5. Wilson, E.O. (1986) Biodiversity, Academic press Washington
6. Wagher, R.H. (1974) Environment and Man. (Second Edition), Norton, New York.

Practical

1. Visit to an area to document environmental assets including natural resources/flora/fauna, etc.
2. Identification and study of common insects, fish, birds, mammals of a particular area.
3. To determine the physical conditions of water: Depth, Viscosity, Density, Buoyancy.
4. To determine the chemical conditions of water: pH, dissolved oxygen and carbon-di-oxide, hardness etc.
5. To determine Cl, SO4, NO3 in soil and water samples from different locations.
6. To study acidity and alkalinity of sample water by methyl orange and phenolphthalein
7. Visit to a local polluted site (Urban/Rural/Industrial/Agricultural).

   Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-9**	**Bioeconomics**	Theory:04 Practical: 02 Total: 06

About the course

This course focuses on the biodiversity assessment or assessment of ecosystem components for their sustenance over a long period of time. The consequences of globalization and shrinking boundaries of planet prompt for economic eco-solutions.

Learning outcomes

On the completion of the course, the students shall be able to

- Understand different concepts related to ecological economics
- Analyze multi-disciplinary approaches related to ecological, economic and social dimensions for sustainable development
- Evaluate the economic explanations and solutions for environmental problems
- Reflect upon the implications of increasing globalization for sustainable ecosystems

Theory

Unit I: Multidisciplinary approaches for sustainable development **12 Lectures**
Multi-disciplinary approaches related to ecological, economic and social dimensions for sustainable development. Economics versus ecology, economic growth versus sustainable development; Carrying capacity; sustainable or renewable resources, 2nd law of thermodynamics, environmental perspective of entropy; its application.

Unit II: Natural resources, ecosystem services **16 Lectures**
Ecosystem Services. Categories of ecosystem services, Biodiversity and its importance, ecosystem resilience, effects of biodiversity on ecosystem services, biophysical and human factors affecting the delivery of ecosystem services, monitoring of ecosystem services. Millennium Ecosystem Assessment; planetary boundaries in relation to economic growth and sustainable development; Sustainability indicators; Eco-labelling;

Unit III: Efficient and equitable allocation of resources **11 Lectures**

Economic value of the world's ecosystems and services, Economic explanations to and solutions for environmental problems, Environmental economic valuation methods. standard market prices, benefit-cost ratio, net present value, present value ratio, value ecosystem services that are not traded in the market place. Efficient and equitable allocation of resources.

Unit IV: Ecosystem health management **13 Lectures**

Spatial scale – Sustainability and the green footprint, measuring ecosystem health, implications of increasing globalization for sustainability. Temporal scale: Equity and discounting the future, opportunity cost, Resource use incentives and property rights, Private, common, and public property rights and limitations, defendable rights to resources.

Recommended readings

1. Mayumi, K., Martinez, J. (2012). The Origins of Ecological Economics: The Bioeconomics of Georgescu-Roegen .Routledge; 1 edition.
2. Vandenbergh, J.C.V.M., Hoekstra, J., Imeson, R., Nunes, P.A.L.D. (2010). Bioeconomic Modelling and Valuation of Exploited Marine Ecosystems. Springer; Softcover reprint of hardcover 1st ed. 2006 edition.
3. Heun, M.K., Dale, M.C. and Haney, B.R. (2016) Beyond GDP: National Accounting in the Age of Resource Depletion.Springer; Softcover reprint of the original 1st ed. 2015 edition.
4. Wagner, J. E. (2011) Forestry Economics. Routledge Press
5. Daly, H. and Farley, J. (2011). Ecological Economics: Principles and Applications (2nd Ed). Island Press, Washington D.C.
6. William, J. G. (2005). Investing in Nature: Case studies of land conservation in collaboration with business. Island Press, Washington, D.C.
7. Daily, G. C. and Ellison, K. (2002). The New Economy of Nature: The quest to make conservation profitable.
8. Assessment, M.E. (2005). Ecosystems and Human Well-being: Synthesis and Biodiversity Synthesis. Washington, DC: WRI

Practical

1. Visit any nature-park / agricultural field / forest/ Garden and count the living organisms
2. Identify the Natural resources – water, fresh air, soil, plants/trees, animals and measure them
3. Attempt to find its costs in terms of use in the ecosystem
4. Try to evaluate the impact of each service rendered by each resource independently and in combination
5. Try to evaluate the contingent value of the scenic beauty by travel cost method
6. Evaluate the potential of manure production value of the plants and animals there.

7. Learn the statistical tools for analysis and interpretation of the data.
8. Methods of measurement of wood volume of standing trees and logs, wood density, specific gravity, yield, and non woody products.
9. Protection of woody and non woody plants from fire and pathogens.
10. Statistical analysis of the data
11. Evaluation of Biomass
12. Evaluation of floor bioproducts- oil, fodder, fruits, manure.
13. Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28).

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-10**	**Systematics and Evolutionary biology**	Theory:04 Practical: 02 Total: 06

About the course

The course provides information about the patterns and processes of evolution above the species level. Besides elaborating the process of speciation, it also categorically differentiates between the three methods of phylogenetic analysis *viz*., evolutionary systematics, phonetics and cladistics.

Learning outcomes

At the end of the course the students will be able to

- Understand the historical development of systematics from 18th century to the present.
- Understand the complexities of character coding.
- Understand the similarities and differences of different types of data.
- Understand the uses and limitations of phylogenetic trees.
- Appreciate the complexities and difficulties of various species concepts.
- Gain a basic grasp on the rules and philosophy of nomenclature.
- Know about the steps required to do systematic.
-

Theory

Unit I: Biodiversity, systematic and biological classification **14 Lectures**

Biodiversity and human welfare, mega diversity regions and biodiversity hot spots with special reference to India. The science of biodiversity inventory. Systematics and taxonomy. Levels of taxonomy: alpha, beta and gamma taxonomy. Micro and macro taxonomy. Scope and application of taxonomy. Systematics. Relevance of Systematics in Biology and Biological Classification. Phenetic and Cladistics concepts. Analyses through dendogram and cladogram.

Unit II: Species concept and barcoding **12 Lectures**

Biological Species concept, Subspecies, Monotypic and Polytypic species, Sibling species. Reproductive and geographical isolation and their role in speciation process (pre mating and post mating). Speciation modes–Sympatric, Allopatric and Parapatric. Type concept –name bearing types (primary and secondary) and their applications. DNA bar coding for identification of species.

Unit III: Natural selection, genetic drift etc. **12 Lectures**

History of Origin of life through molecules. Natural selection: Concept of selection: stabilizing, directional and disruptive changes, Hardy-Weinberg equilibrium; estimating allele and genotype frequency, frequency changes in mutation and migration. Genetic drift, founder effect and population bottleneck.

Unit IV: Species distribution and adaptive radiations **14 Lectures**

Bathymetric and discontinuous distribution. Barriers and dispersals -types and their impact on animal distribution. Zoogeographical realms –names and distribution of animal according to Wallace scheme, Avian and Mammalian faunal distribution in different realms. Some distinct events in evolution: Adaptative radiations with special reference to Darwin's finches. Origin of birds. Evolution in horse. Xeric (camel and lizard); Arboreal (sloth bear) adaptation.

Recommended readings

1. Futuyama, D. J. (1986). Evolution, Systematics and Animal Behaviour. Evolutionary Biology. Sinauer Associates Inc.
2. Strickberger, M. W. (2007). Evolution. CBS Pub.
3. Colbert, E. H.; Morales, M. & Minkoff, E. I. (2001). Evolution of the Vertebrates, Science.
4. Moody, P. A. (2002). Introduction to Evolution, Kalyani Pub.
5. Dobzhansky, T.; Ayala, F. J.; Stebbins G. L. and Valentine, J. W. (1979). Evolution, Surjeet Pub.
6. Mayr, E. & Ashlock, P. D. (1991) Principles of Systematic Zoology (2^{nd} edition) McGraw Hill Int.
7. Simpson, G. G. (1962) Principles of Animal Taxonomy, Oxford IBH.
8. Darlington, P. J. (1966) Zoogeography (4^{th} edition) John Wiley.

Practical

1. Compilation of a data matrix using characters, character states and construction of classifications which reflect the "relationships" among the taxa
2. The data matrix to be used to construct a key to identification of the taxa.
3. Phylogeny Inference Package (PHYLIP): Programs for distance and character-state data; making consensus trees; DNA sequence programs; and maximum likelihood.
4. Selection of five species (preferably invertebrates, insects) belonging to a clade. A project work on their identification, illustration and assessment of their relationship by constructing a cladogram using characters and character states.
5. Comparison of two species of birds belonging to same species but different subspecies (Intraspecific difference).

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28)

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-11**	**Global Environmental Issues**	Theory:04 Practical: 02 Total: 06

About the course

This course focuses on the diversity of living forms particularly animals with a detailed inference on the loss of species due to various reasons and the need of their conservation.

Learning outcomes

At the end of the course the students will be able to:

- Understand the fundamental issues of environment.
- Analyze different sources of environmental problems and methods of measurement of pollution.
- Examine economic growth and quality of life.
- Examine the microbiology of waste water treatment and its various schemes.
-

Theory

Unit I: Environment and Environmental Problems **13 Lectures**

Basic concepts and issues, global environmental problems - ozone depletion, UV-B, greenhouse effect and acid rain due to anthropogenic activities, Fisheries depletion, Eutrophication, their impact and biotechnological approaches for management.

Unit II: Environmental Pollution **11 Lectures**

Environmental pollution - types of pollution, Air, water and land pollution. sources of pollution, measurement of pollution, fate of pollutants in the environment, Ocean acidification, Bioconcentration, bio/geomagnification.

Unit III: Environmental Economics **12 Lectures**

Environmental Economics : Basic concept; methods of evaluation; Economic growth, Gross National Productivity and the quality of life, Tragedy of Commons, Economics of Pollution control, Cost-benefit ratio and cost effectiveness analysis.

Unit IV: Use of Microbes in Waste Water Treatment **15 Lectures**

Aerobic decomposition process - activated sludge, oxidation ponds, trickling filter, towers, rotating discs, rotating drums, oxidation ditch. Anaerobic decomposition process - anaerobic filters, up- flow anaerobic sludge blanket reactors. Treatment schemes for sewage from dairy, distillery, tannery, sugar and pharma industries.

Recommended readings

1. Frances, H. (2012). Global Environmental Issues (2nd edition) Willey-Blackwell
2. Mahesh, R. (2007) Environmental Issues in India: A Reader. Pearson-Longman.

Practical

There are no structured class lab experiments involved. However the students are expected to visit various sites on the web, make teams for group-discussion indulge in debates, collect justifiable information from various sources, make historical report on the following major global environmental issues :

1. Atmosphere Management: Pollution, global warming/climate change, Stratospheric ozone depletion its impact and possible solutions
2. Fresh water Management: Pollution, reasons, severity of problem, impact for the present and the future, its impact and possible solutions
3. Marine Ecosystem: Pollution of marine ecosystem, its impact and possible solutions
4. Soil degradation and Desertification
5. Solid Waste Management
6. Human health and Toxicology

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28)

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-12**	**Environmental Monitoring and Management**	Theory:04 Practical: 02 Total: 06

About the course

This course focuses on the diversity of living forms particularly animals with a detailed inference on the loss of species due to various reasons and the need of their conservation.

Learning outcomes:

On the completion of the course the students shall be able to

- Understand the fundamental concepts of environmental monitoring and management
- Analyze the different methods of air, water, and soil quality monitoring process
- Examine different environmental management systems and trade related intellectual properties (TRIPs), intellectual property rights (IPRs).
- Evaluate the status of environmental education and public awareness along with their implications

Unit I: Concept note on environment **13 Lectures**

Concept and Approaches for environment, environmental science, global concerns about environment, Environmental Protection and sustainability: principles of sustainability, structure of natural systems, causes of land degradation and environmental pollution, population growth and environment Monitoring, Legal and institutional status of environment.

Unit II: Air Quality, Water Quality and Solid Quality Monitoring **11 Lectures**

Ambient and indoor air quality monitoring; Methods of collection and analyses of gaseous and particulate pollutants, air pollution standards. Monitoring of agricultural systems and aquatic habitats: understanding the degradation processes, steps of environment monitoring: indices and indicators

Unit III: Biomonitoring, Instrumentation **12 Lectures**

Passive and active biomonitoring, bioindication, bioindicator parameters; zonation study. Principles of chromatography, spectrophotometry, electro-analytical and radio-analytical techniques.

Unit IV: Environmental Management System and Ethics **16 Lectures**

Environmental management system (EMS): ISO-14000; Environmental audit; Environmental clearance for establishing industries; Environmental Impact Assessment (EIA); EIA guidelines, Environmental taxes International trade and environment; Trade Related Intellectual Properties (TRIPs), Intellectual Property Rights (IPRs). Environmental education, public awareness, peoples participation in resource conservation and environmental protection.

Recommended readings

1. Sawyer, C. N.; McCarty, P. L. and Parkin, G. F. (2002). Chemistry for Environmental Engineering and Science. John Henry Press.
2. Rump, H. H. (2000). Laboratory Manual for the Examination of Water, Waste water and soil. Wiley-VCH.
3. Sapru, R. K. (1987). Environmental Management in India (Vol. I & II). Ashish Publishing House.
4. Bryan, F.J. Manly. (2009). Statistics for Environmental Science and Management. CRC Press.
5. Naik, S.C. and Tiwari, T.N. (2006). Society and Environment. Oxford & IBH Publishers.
6. Santra, S.C. (2011). Environmental Science. New Central Book Agency.

Practical

1. Monitoring of dust load at different sites.
2. Rapid soil test for pH, alkalinity, nitrate, oxidizing potential.
3. Rapid water quality test for temperature, pH, nitrate.
4. Identification of water bloom forming micro-organisms.
5. Visit to sophisticated environmental analysis lab.
6. Field work for resource conservation and environmental protection.
7. Project Report on a visit to a Sewage treatment plant / Marine bio-reserve/Fisheries Institutes.

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28)

Semester	Course	Course Title	Credit
I/ II/ III/ IV	**GEC-13**	**Basics of Systematics and Classification**	Theory:04 Practical: 02 Total: 06

About the course

. The course will provides a comprehensive survey of the theory and methodology of systematics as they are applied today to all groups of organisms. The course is directed at those students interested in studies of evolutionary biology, biodiversity, conservation biology, and/or systematics.

Learning outcomes

At the end of the course the students will be able to;

- Comprehend the basic concepts of animal taxonomy and zoological nomenclature
- Evaluate the significance of museum specimens
- Analyze the implications of biometrics, numerical taxonomy and cladistics.
- Understand the historical development of systematic biology from the 18th century to the present.
- Gain a basic grasp on the rules and philosophy of nomenclature.
- Question what you know, and need to know, to do systematic.
- Develop the capacity to critically evaluate the primary literature.
-

<u>Theory</u>

Unit I: Introduction to systematic and classification **13 Lectures**

Kinds and diversity of living forms. Biogeographical zones; Endemism. Importance of collections/ museum specimens of the world and India; Documentation of biodiversity. Systematics and taxonomy. Importance and basis of classification. Heirarchy of classification and classification systems. Types of classification-artificial, natural and phylogenetic.

Unit II: Taxonomic treatment and phylogenetics **14 Lectures**

Systematic data: kinds of data. Taxonomic treatment of allopatric variation, homology; Reproductive isolating mechanisms; Hybridization and introgression; Polyploidy; Modes of speciation. Principles and criteria of taxonomic treatment: Taxonomic evidence: Characters and character states. Taxonomic characters; OTUs, character weighting, cluster analysis; Phenetics, Evolutionary taxonomy, Cladistics. Constructing trees/ dendrograms: Phenogram, phylogram and cladogram and turning them into classifications.

Unit III: Molecular phylogenetics **12 Lectures**

Molecular phylogenetics: Gene structure, mutation and rates and patterns of nucleotide substitutions. Mitochondrial genome. Molecular "clock" hypothesis. Phylogeny estimation methods: Distance data, Maximum-parsimony, Maximum-likelihood etc. Cladogram reliabilities, Molecular characterization versus morphological characterization: Conflict or compromise?

Unit IV: International code of Nomenclature **13 Lectures**

Identification, Description, Naming of taxa. Keys: indented and racketed keys. Principles and rules of International Code of Nomenclature (ICN), binominal system, type material, author citation, criteria for publication, types of names, principle of priority and its limitations. curation of taxonomic collections. Taxonomic revision. Taxonomic literature. The relevance of systematics in conservation programmes.

Recommended readings

1. Mayr, E. and Ashlock, P.D. (1991). Principles of Systematic Zoology. (2nd edition) New York: McGraw Hill, Inc.
2. Quicke, D. L. J. (1993). Principles and Techniques of Contemporary Taxonomy. New York: Chapman and Hall

Practical

1. General discussion, distinguishing characters and classification of selected animals.
2. Preparation of identification keys for select specimens of non chordate (e.g., insects) and chordates (e.g., birds)
3. Generation of a character-state matrix by selecting and scoring diagnostic taxonomic characters.

4. Interactive software for exploring phylogeny and analyzing character state to construct dendrogram.

5. Distance-based methods of phylogenetic reconstruction using manual and computer methods.
6. Molecular data analysis by aligning sequences and constructing trees using PAUP

Group discussion or Seminar presentation on one or two related topics from the list (page no. 25-28)

Ability Enhancement Courses

Semester	Course	Course Title	Credit
I/ II	**AEC-1**	**Science Communication and Popularization**	Theory:04

About the course

The course highlights the importance of science communication and popularization and its role in human development.

Learning outcomes:

After the completion of this course, the learner will be able to:

- Utilize visual media science communication for creating scripts and documentaries.
- Identify the need and role of science communication in human development.
- Contribute in science popularization through internet communication and public Sensitization.

Unit-I: Print Science Communication **16 Lectures**

Value of Science Journalism: Science's potential for breaking news. Role of science and technology in human development. Framing policies at national and international levels. Writing and communicating popular articles effectively, case studies of celebrated works of science communicators including Cosmos by Carl Sagan, works of Bill Bryson, Richard Dawkins, Richard Feynman, Isaac Asimov, Carl Zimmer and Matt Riddley, importance for communication through regional languages.

Unit-II: Visual Media Science Communication **13 Lectures**

Science outreach through visual media: Creating science documentaries, creating the outline and expanding, scripts, citing authentic sources, case study: Famous documentaries of Carl Sagan, David Attenborough and Prof. Yashpal. Cultural Studies of Science and Technology- technoscientific culture- Science Fiction Studies-cinema and science-Science in Indian popular culture.

Unit-III: Internet Science Communication **10 Lectures**

Science popularization through internet: Social media, Websites, Blogs, You tube, Podcast etc. sensitization on important issues like climate change, deforestation, biodiversity loss, important of science etc.

Unit-IV: Science Outreach Talks and Public Sensitization **13 Lectures**

Tactics for providing a charismatic and effective public talk, use of metaphors, speaking in context, Museum displays and public exhibitions Science outreach for biodiversity conservation sensitization of public. Science communication during disasters- Public Engagement with Science and Technology, public sphere-multiple publics-the deliberative turn

Recommended readings

1. Selected works of Carl Sagan, works of Bill Bryson, Richard Dawkins, Richard Feynman, Isaac Asimov, Carl Zimmer and Matt Riddley.
2. Gigante, E. Marie (2018). Introducing Science Through Images: Cases of Visual Popularization (Studies in Rhetoric/Communication), University of South Carolina Press.

Semester	Course	Course Title	Credit
I/ II	**AEC-2**	**Good Laboratory Practices**	Theory:04

About the course

This course was designed to improve knowledge and understanding of the requirements of good laboratory practices which encompasses facility and equipment requirements, documentation requirements, roles and responsibilities and outsourcing services.

Learning outcomes

After completing this course, the students will be able to:

- Apply practical skills in science courses with the understanding of general laboratory practices
- Use various micro techniques used in Zoology
- Apply various techniques to study animal tissues
- Explore various research issues and their solutions

Unit-I: General Laboratory Practices **14 Lectures**

Understanding the details on the label of reagent bottles. Preparation of solutions. Molarity and normality of common acids and bases. Dilutions. Percentage solutions. Molar, molal and normal solutions. Technique of handling micropipettes; Knowledge about common corrosive and toxic chemicals and safety measures in their handling. Maintenance of equipments.

Unit-II: Tissue Micro-Techniques **12 Lectures**

Weighing and staining procedures, classification and chemistry of stains. Staining equipment. Reactive dyes and fluoro-chromes (including genetically engineered protein labeling with GFP and other tags). Cytogenetic techniques with squashed tissues.

Unit-III: Methods to Study Tissue Structure 14 Lectures

Whole mounts, squash preparations, clearing, maceration and sectioning; Tissue preparation: living *vs* fixed, physical *vs* chemical fixation, coagulating fixatives, non-coagulant fixatives; tissue dehydration using graded solvent series; Paraffin; Preparation of thin and ultrathin sections.

Unit-IV: Overview of Biological Problems 12 Lectures

History; Key relevant problems associated in Zoology research areas, their solution and basic understanding of animal models. Idenifying sources of hazards e.g., poisonous chemicals, Broken glass, Explosion, Fire. Safety/First aid measures: Fume hoods, eye fountain, emergency shower, fire extinguisher, eye protection gear, Sample collection, recording of data. Analytical quality control

Recommended readings

1. Seiler, J.P. (2005). Good Laboratory Practices: the why and how. Springer-Verlag Berlin and Heidelberg GmbH & Co. K; (2nd edition).
2. Garner, W.Y., Barge, M.S. and Ussary, P.J. (1992). Good Laboratory Practice Standards: Application for field and Laboratory studies. Wiley VCH.

Semester	Course	Course Title	Credit
I/ II	**AEC-3**	**Basic Mathematics for Zoologists**	Theory:04

About the course

The course offers the zoology student an opportunity to learn basic mathematical principles for their effective use in solving biological problems and in data interpretation.

Learning outcomes

After the end of the course, the students will be able to:

- Understand the different Graphs and Functions of Basic Mathematics
- Recognize simple functions of basic Mathematics.
- Evaluate slope of curves and derivatives of different functions
- Apply various types of Differentiation and Integration in biology
- Comprehend the interrelationships among different components of Algebra

Unit I: **Applications of mathematics in Biology** **13 Lectures**

Mathematics as a language, Need of learning mathematics, Applications of mathematics in Biology. Graphs and functions: Linear function, Quadratic function, Exponential function, Periodic functions, Combination of simple functions, Examples from Biology, Logarithmic function, Slope of curves, Idea of derivatives.

Unit II: **Integrationand its application in biology** **13 Lectures**

Calculus: Differentiation and its applications to biology, Integration and its applications to biology. Indefinite integrals, integration of simple functions, Integral as "anti-derivative" Definite integrals, Integral as area under a curve, Integration by parts, Finding derivative and integral given a set of data points.

Unit III: Algebra and its applications 13 Lectures

Algebra: Basics of algebra, Linear algebra, Eigenvalues, Differential equations, Simple differential equations, First order differential equations, Examples: Polymerizing and depolymerizing filaments, Partial differential equations, Vector algebra.

Unit IV: Fourier series, plotting functions 13 Lectures

Fourier Series: Introduction to Fourier series, Fourier coefficients, Calculation of Fourier series for simple functions, Sum of periodic functions. Plotting functions using computer, gnuplot demonstration, numerical calculations, Interpolation

Recommended readings

1. NPTEL Course on Biomathematics accessible at https://nptel.ac.in/syllabus/102101003/
2. Cann, J.A. (2002). Maths from Scratch for Biologists. Wiley
3. D'Arcy Wentworth Thompson (1992). On Growth and Form: The Complete Revised Edition, Dover Books on Biology.
4. Ahmad, V.U., and Basha, A. (2010). Spectroscopic Data of Steroid Glycosides: Volume 1. Springer; Softcover reprint of hardcover 1st ed. 2007 edition.
5. Aitken, M.; Broadhursts, B. and Haldky, S. (2009). Mathematics for Biological Scientists, Garland Science.
6. Batschelet, E. (2003). Introduction to Mathematics for Life Scientists (3rd edition) Springer Verlag
7. Murray, J.D. (1989). Mathematical Biology, Springer.
8. Sneyd, J. and Keener, J. (2000). Mathematical Physiology, Springer.
9. Fall, C.P. *et al.* (2002) Computational Cell Biology, Springer.

Semester	Course	Course Title	Credit
I/ II	**AEC-4**	**Research Methodology**	Theory:04

About the course

The aim of the course is to familiarize students with basics of research and the research process; provide an introduction to research methods and report writing; give insight into various kinds research design and sampling.

Learning outcomes

At the end of the course the students will be able to,

- Understand the concept of research and different types of research in the context of biology
- Have basic awareness of data analysis-and hypothesis testing procedures
- Develop laboratory experiment related skills.
- Have basic knowledge on qualitative research techniques
- Develop competence on data collection and process of scientific documentation
- Analyze the ethical aspects of research
- Evaluate the different methods of scientific writing and reporting

Unit-I: Basic Concepts of Research **16 Lectures**

Research-definition and types of research (Descriptive *vs* analytical; applied *vs* fundamental; quantitative *vs* qualitative; conceptual *vs* empirical). Research methods *vs* methodology. Literature-review and its consolidation; Library research; field research; laboratory research.

Unit-II: Data Collection and Documentation of Observations **12 Lectures**

Maintaining laboratory record; Tabulation and generation of graphs. Imaging of tissue specimens and application of scale bars. The art of field photography.

Unit-III: Overview of Biological Problems **12 Lectures**

History; Key biology research areas, Model organisms in biology (A brief overview): Genetics, Physiology, Biochemistry, Molecular Biology, Cell Biology, Genomics, Proteomics-Transcriptional regulatory network.

Unit-IV: Ethics and Art of Scientific Writing **12 Lectures**

Authors, acknowledgements, reproducibility, plagiarism, Numbers, units, abbreviations and nomenclature used in scientific writing. Writing references. Power-point presentation. Poster presentation. Scientific writing and ethics, Introduction to copyright-academic misconduct/plagiarism.

Recommended readings

1. Dawson, C. (2002). Practical research methods. UBS Publishers, New Delhi.
2. Stapleton, P., Yondeowei, A., Mukanyange, J., Houten, H. (1995). Scientific writing for agricultural research scientists – a training reference manual. West Africa Rice Development Association, Hong Kong.
3. Ruzin, S. E. (1999). Plant microtechnique and microscopy. Oxford University Press, New York, U.S.A.

Semester	Course	Course Title	Credit
I/ II	**AEC-5**	**History of Indian Science**	Theory:04

About the course

The course provides an insight into the status of science in ancient India, its gradual development, innovations and the pioneers in the field of science, reputed research institutions in India and cutting edge research in science.

Learning outcomes

On completion of this course, the students will be able to

- Develop understanding of various branches of science during different eras
- Analyze the role played by different Indian organizations in science
- Appraise the contribution of different Indian Scientists.

Unit-I: Science in Ancient and Medieval India 14 Lectures

History of development in astronomy, mathematics, engineering and medicine subjects in Ancient India, Use of copper, bronze and iron in Ancient India, The geography in literature of Ancient India. Influence of the Islamic world and Europe on developments in the fields of mathematics, chemistry, astronomy and medicine, innovations in the field of agriculture-new crop introduced new techniques of irrigation.

Unit-II: Indian Science in before and after Independence 12 Lectures

Introduction of different surveyors, zoologists and doctors as early scientist in Colonial India, Indian perception and adoption for new scientific knowledge in Modern India, Establishment of premier research organizations like CSIR, DRDO and ICAR and ICMR, IIT's, Establishment of Atomic Energy Commission, Launching of the space satellites, ISRO's accomplishments. Zoological survey of India.

Unit-III: Prominent Indian scientists 14 Lectures

Eminent scholars in mathematics and astronomy: Baudhayana, Aryabhatta, Brahmgupta, Bhaskaracharya, Varahamihira, and Nagarjuna, Medical science of Ancient India (Ayurveda and Yoga): Susruta, Charak. Scientists of Modern India: Srinivas Ramanujan, C.V. Raman, Jagdish Chandra Bose, Homi Jehangir Bhabha,Vikram Sarabhai etc.

Unit-IV: Prominent research in Animal Sciences in Republic of India 12 Lectures

History of animal tissue culture with context to India; green, while and pink revolutions in India: causes, details, and outcomes. The pioneers associated with. First gene cloning, First genome sequencing from India. Premier Research institutes and current eminent scientists in India, GM organisms.

Recommended readings

1. Kuppuram, G. (1990) History of Science and Technology in India, South Asia Books.
2. Handa, O.C. (2014) Reflections on the history of Indian Science and Technology, Pentagon Press.
3. Basu, A. (2006) Chemical Science in Colonial India: The Science in Social History, K.P. Bagchi & Co.
4. Habib, I. (2016) A people's history of India 20: Technology in Medieval India, 5th Edition, Tulika Books.
5. Rahman, A. *et al* (1982) Science and Technology in Medieval India – A Bibliography of Source Materials in Sanskrit, Arabic and Persian, New Delhi: Indian National Science Academy.
6. Subbarayappa, B.V. & Sarma, K.V. (1985), Indian Astronomy -– A Source Book, Bombay.
7. Srinivasan, S., Ranganathan, S. (2013) Minerals and Metals heritage of India, National Institute of Advanced Studies.
8. Srinivasiengar, C.N. (1967) The History of Ancient Indian Mathematics, World Press Private Ltd. Calcutta.
9. Bhardwaj, H.C. (2000) Metallurgy in Indian Archaeology. Tara Book Agency

Semester	Course	Course Title	Credit
I/ II	**AEC-6**	**Personality Development**	Theory:04

About the course

The course includes diverse aspects of personality development including the principles and methods to achieve success by enhancing psychological skills and time management abilities. The course also deals with ways of human resource improvement by enhancing creativity and thinking skills.

Learning outcomes

After the completion of this course, the students will be able to:

- Develop understanding of the concepts and principles of basic psychological skills
- Apply techniques and methods to enhance productivity and time management
- Develop critical thinking and managerial skills
- Organize human resources with improved leadership qualities

Unit-I: Basic Psychology Skills **13 Lectures**

Mental Heuristics and Priming, Cialdini's six psychological principles, Self Awareness and Self Development: Self appraisal, thoughtful and responsible approach, value and belief system, perception and attitude. Charisma and charisma enhancements, facing interviews.

Unit-II: Productivity and Time Management **13 Lectures**

Eisenhower Matrix, Pomodoro Technique, Dealing with Procrastination, Journaling methods, Checklists, to-do lists and scheduling the events. Swot analysis. Identifying one's strength and failures. Knowing

Unit-III: Dealing Negativity **13 Lectures**

Work-life balance, stress management, coping with failures and depression. Interpersonal skills and communication skills, learning about commitment and how to move things forward, making key decisions

Unit-IV: Critical Thinking and Human resources **13 Lectures**

Logical fallacies, Cognitive biases, Mental Models, Critical Thinking. Evaluation and improvement; Leadership qualities. Leading by example, effective feedback, ethical reasoning.

Recommended readings

1. Bast, F. (2016) Crux of time management for students. Available at: https://www.ias.ac.in/article/fulltext/reso/021/01/0071-0088
2. Cialdini, R.B. (2001) Influence: The Psychology of Persuasion, Revised Edition. Harper Collius.
3. Green, C.J. (2015) Leadership and soft skills for students: Empowered to succeed in High School, College and beyond. Dog Ear Publishing.
4. Velayudhan, A. and Amudhadevi, N. V. (2012) Personality Development for College Students. LAP Lambert Academic Publishing.

Semester	Course	Course Title	Credit
I/ II	**AEC-7**	**Human Health and Sex Education**	Theory:04

About the course

The course is designed to address problems associated with health and sex thereby, promoting fitness and well being.

Learning outcomes

After the completion of this course, the students will be able to:

- understand the importance of good health.
- observe clean sexual habits thereby warding off sexually transmitted diseases.

Unit I: Health: Physical and spiritual **14 Lectures**

Health as a state of wellbeing, health awareness, Physical health, immunization and vaccination, healthy food, balanced diet, food supplements, proper sleep, exercise and keeping away from stress, pathogens and pollution. Reproductive health, adolescence, senescence. Prevention from mental illness and disabilities, alcoholism, tobacco addiction, de-addiction, lifestyle diseases. Community health centres, role of health centres. Spiritual health, yoga and meditation.

Unit II: Human reproductive and developmental cycle **14 Lectures**

Human reproductive system: structural details of male reproductive system, semen, hormonal control. Female reproductive system- structure of ovary, accessory structures, puberty, reproductive cycles and hormonal control, menstrual cycle, gestation period, hysterectomy, menopause. Events of human reproduction: Gametogenesis- spermatogenesis and oogenesis, ovulation, fertilization, embryonic development, parturition.

Unit III: Infertility and assisted reproductive techniques **12 Lectures**

Human intervention in reproduction: Contraception and birth control-barrier method, hormonal methods, natural methods, sterilization, termination of pregnancy. Infertility-male and female infertility, causes and treatment for infertility. Advanced Reproductive Technologies- IVF, GIFT, ZIFT, Donor Insemination (DI). Sperm transfer techniques. Surrogacy.

Unit IV: Sex education and prevention from Sexually transmitted diseases **12 Lectures**

Sexually transmitted diseases: Syphilis, genital warts, chlamydia, chancroid, trichomoniasis, gonorrhea, genital herpes, AIDS, Sex education: Adolescent sexual activity, teenage pregnancy, sexual harassment, sexual awareness and policies (legal aspects), lesbian and gay sex, bisexual, transgender youth, adolescent stress management

Recommended readings

1. Kothari P. (1994) Common sexual problems and solutions by, UBS Publishers and Distributors Ltd.
2. Hadley, Mac. E.. (2004) Endocrinology. (5th edition) Pearson Education, Singapore.
3. Taylor, D.J., Green, N.P.O., Stout G. W. (2005) Biological Science. (Editor R. Soper) 3rd Edition, Cambridge University Press.
4. The Complete Manual of Fitness and Well-being. The Reader's Digest Association, Inc. Pleasantville, New York / Montreal.
5. Guyton, A.C. and Hall, J.E..Textbook of Medical Physiology.

Semester	Course	Course Title	Credit
I/ II	**AEC-8**	**Human Nutrition**	Theory:04

About the course

The course deals with the importance of nutrition in maintaining health; the essential nutrients, balanced diet, the calories associated with different food items and the factors affecting the fitness in humans, food sanitation and hygiene.

Learning outcomes

After the completion of this course, the students will be able to:

- Know about essential nutrients and required macro and micro nutrients
- Cultivate proper feeding habits.
- Learn the proper and scientific value of different food items.
- Know caloric value of the food items

Unit I: Carbohydrate and protein as important food sources 13 Lectures

Introduction and scope. Carbohydrates, Proteins and Lipids – Carbohydrates: Functions, classification, food sources, storage in body, biomedical importance. Brief outline of metabolism : glycogenesis & glycogenolysis (in brief), glycolysis, citric acid cycle. Clinical significance. Proteins - Functions, classification, food sources, composition, essential & non-essential amino acids, protein deficiency. biomedical importance. Metabolism: Transformation, Decarboxylation, Ammonia formation & transport, Urea cycle. Clinical significance.

Unit II: Fat as a source of energy 13 Lectures

Fats & oils: Function of fats, classification, food sources, composition, saturated and unsaturated fatty acids, biomedical importance, essential fatty acids. Brief out line of metabolism: Beta oxidation of fatty acids, Ketosis, Cholesterol. Clinical significance. Vitamins and minerals - sources and functions, deficiency status. Minerals - macro & micronutrients; functions, sources. Bioavailability and deficiency of Calcium, Iron, Iodine, Sodium & Potassium. Water: importance as a nutrient, function, sources, requirement, water balance & effect of deficiency.

Unit III: Nutritional requirements and calories of a balanced diet 12 Lectures

Basal metabolic rate, energy requirements of man, women, infants and children. Nutritional value of foods- cereals, fruits, milk, egg, meat, fish. Balanced diet, Nutrition requirements as per physiological stages of pregnancy, food selection, complication of pregnancy. Nutrition requirements during lactation and during infant growth and development, breast feeding, infant formula, introduction of supplementary diet.

Unit IV: Malnutrition and health requirements **14 Lectures**

Nutritional requirement and growth in preschool children growth, Nutritional requirement of school children., importance of snacks, school lunch. Nutritional needs and feeding pattern during adolescence and adulthood. Geriatric nutrition: Factors affecting food intake and nutrition related problems. Foods of nutritional value, Balanced diet, Malnutrition, Use of food in body. Role of fibres in human nutrition; Effect of cooking and heat processing on the nutritive value of foods; Processed supplementary foods; Food sanitation in hygiene.

Recommended readings

- Gopalan, C., Ramasastri, B.S. & Balasubramanian, S.C. (1971). Nutritive value of Indian foods. National Institute of Nutrition, Hyderabad.
- Gopalan, D. & Vijayaraghavan, K. (1971). Nutrition atlas of India, ICMR, New Delhi.
- Ghosh, S. (1981). The feeding care of infants and young children, UNICEF, New Delhi.
- Mudambi, S.R. (1995). Fundamentals of food and nutrition. New age international, New Delhi.
- Swaminathan, M. (1989). Handbook of food and nutrition. Bappco, Bangalore.
- Swaminathan, M. (1974). Essentials of food and nutrition. Vol I & II, Ganesh and Co. Madras.

Semester	Course	Course Title	Credit
I/ II	**AEC-9**	**Intellectual Property Rights**	Theory:04

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About the course

The present course gives a detailed account of intellectual property right (IPR), its genesis and scope, the steps involved in submitting and publication of patent; trademark and copyright rules.

Learning outcomes

On completion of this course, the students will be able to:

• Understand the concept of IPR

• Differentiate between various agreements of IPR

• Compare between copyrights, patents and Geographical Indicators

• Examine various legal issues related to IPR

• Relate to various cyber issues concerning IPR

Unit-I: Introduction to Intellectual Property Right (IPR) **12 Lectures**

Copyright Act and IPR and its importance. IPR in India and other coutries of the world: Genesis and scope. IPR and WTO (TRIPS, WIPO). Objectives, Rights, Patent treaty, 1970 and its amendments.

Unit II: Patents, Copyrights and Trademarks **13 Lectures**

Protocol of obtaining patents, Industrial Application - Non - Patentable Subject Matter - Registration Procedure, Rights and Duties of Patentee, Licence; Infringement of patents, Patent office. Copyrights: type of work protected under copyright laws, Rights, Transfer of Copyright, Infringement and penalties. Trademarks: Objectives, Rights of holder, Assignment, Infringement, Remedies and Penalties.

Unit-III: Protection of Traditional Knowledge, Industrial Designs **14 Lectures**

Concept of Traditional Knowledge, Holders, Traditional knowledge on the International Arena, at WTO, at National level, International enforcement of intellectual property rights. Bioprospecting and Bio-piracy, Commercial piracy, Transnational lawsuits. Germplasm protection in India. National gene bank, Benefit sharing. Protection of Plant Varieties and Farmers' Rights Act, 2001.

Unit-IV: Other examples of IPR and ethical issues 13 Lectures

Biotechnological Inventions: Objective, Applications, Concept of Novelty, Concept Originality or creativity requirements. Patenting with microorganisms. Ethical issues in Patenting Biotechnological inventions. Computer Software and Intellectual Property, Database and Data Protection, Protection of Semiconductor chips etc.

Recommended readings

1. Gopalakrishnan, N.S. and Agitha, T.G. (2009) Principles of Intellectual Property right. Eastern Book Company, Lucknow.
2. David Kitchin, Q.C.; Llewelyn, D.; Mellor, J.; Meade, R.; Moody-Stuart, T.; Keeling, D. and Jacob, R. (2005) Kerly's Law of Trade Marks and Trade Names (14th Edition) Thomson, Sweet & Maxweel.
3. Narayanan, P. (2010) Law of Copyright and Industrial Designs; Eastern law House, Delhi.
4. Parulekar, A. and D' Souza, S. (2006) Indian Patents Law – Legal & Business Implications; Macmillan India Ltd.
5. Wadehra, B. L. (2000) Law Relating to Patents, Trade Marks, Copyright, Designs & Geographical Indications; Universal law Publishing Pvt. Ltd., India.

Skill Enhancement Courses

Semester	Course	Course Title	Credit
III/ IV	**SEC-1**	**Reproductive Technologies**	Theory:04

About the course

The course is designed for the students to make them aware of the induced release of gametes, multiple ovulation, superovulation, *in vitro* oocyte maturation and cryopreservation of gametes and embryos. It will also explain the causes of infertility and the techniques for intrafallopian and intrauterine transfer and *in vitro* fertilization.

Learning outcomes

At the end of the course the students will be able to

- identify structures and function of reproductive anatomy in the male and female
- identify hormones, their production site, physiology impacts and how to manipulate specific hormones to control reproduction either positively or negatively.
- summarize critical components of reproductive technologies involved in breeding, semen collection, gamete biology and embryonic development.
- communicate via oral, written, podcast, and website modalities.
- recognize how differences based on cultural and ethnicity impact individuals.

Unit-I: Assisted reproductive technologies **15 Lectures**

Scope of reproductive technologies; Induced release of gametes and its significance; Biochemistry of semen composition and formation; Assessment of sperm functions; Role of assisted reproductive technologies in infertile human and animals; Constraints in assisted reproductive technologies; Culture techniques for farm animals' embryos.

Unit-II : Ovulation and implantation **11 Lectures**

Fertilization and implantation. Infertility in male and female individuals: causes, diagnosis and management; Multiple ovulation, superovulation; In vitro oocyte maturation; Cryopreservation of gametes and embryos.

Unit-III : Intrafallopian transfer **11 Lectures**

Intracytoplasmic sperm injection; In vitro fertilization of gametes; Intrafallopian transfer (GIFT) of gamete; Intrafallopian transfer (ZIFT) of zygote; Intrauterine transfer (IUT) of embryo; Transgenic animals and their uses.

Unit-IV. Contraceptive technologies **15 Lectures**

Introduction to contraceptive technologies; Immunocontraception. Antibody mediated infertility; Surgical methods; Oral contraceptives; Injectables; Implants; Intrauterine uterine device (IUD); Physical and chemical barrier methods; Demographic terminology used in family planning.

Recommended readings

1. Jones, R. E. and Lopez, K. H. (2013) Human Reproductive Biology (3rd edition)

Semester	Course	Course Title	Credit
III/ IV	**SEC-2**	**Public Health and Hygiene**	Theory:04

About the course

The course designed for public health and hygiene at graduation level will give understanding for health hygiene, dietary issues, diseases related to malnutrition, communicable and non-communicable diseases.

Learning outcomes

After successfully completing the course, the students will be able to

- Identify current national and global public health problems.
- Aware about the issues of food safety, water safety, vaccination, exercise and obesity, exposure to toxins.
- frame a public health plan during any epidemic or spread of infectious disease etc.
- Analyze case studies of infant mortality and obesity.
- Assess the health inequalities with regard to gender, race, ethnicity, income etc.

Students may make an oral presentation and compare the health care system of India with a country having advanced one.

Unit-I: Maintenance of personal hygiene — 13 Lectures

Introduction to public health and hygiene- determinants and factors. Pollution and health hazards; water and air borne diseases. Radiation hazards: Mobile Cell tower and electronic gadgets (recommended levels, effects and precaution). Role of health education in environment improvement and prevention of diseases. Personal hygiene, oral hygiene and sex hygiene.

Unit-II: Nutrient deficiency diseases — 13 Lectures

Classification of food into micro and macro nutrients. Balanced diet, dietary plan for an infant, normal adult, pregnant woman and old person. Importance of dietary fibres.

Significance of breast feeding. Malnutrition anomalies – Anaemia (Iron and B12deficiency), Kwashiorkar, Marasmus, Rickets, Goiter (cause, symptoms, precaution and cure). Substitution of diet with required nutrients to prevent malnutrition disorders.

Unit-III: Communicable and contagious diseases 13 **Lectures**

Infectious agents responsible for diseases in humans. Communicable viral diseases- measles, chicken pox, poliomyelitis, swine flu, dengue, chickungunya, rabies, leprosy and hepatitis. Communicable bacterial diseases- tuberculosis, typhoid, cholera, tetanus, plague, whooping cough, diphtheria, leprosy. sexually transmitted diseases- AIDS, syphilis and gonorrhoea.Health education and preventive measures for communicable diseases.

Unit-IV: Non-communicable diseases and cure **13 Lectures**

Non-communicable diseases such as hypertension, stroke, coronary heart disease, myocardial infarction. Osteoporosis, osteoarthritis and rheumatoid arthritis-cause, symptom, precautions. Diabetes- types and their effect on human health. Gastrointestinal disorders- acidity, peptic ulcer, constipation, piles (cause, symptoms, precaution and remedy) etc. Obesity (Definition and consequences). Mental illness (depression and anxiety). Oral and lung cancer and their preventive measures.

Recommended readings

1. Mary Jane Schneider (2011) Introduction to Public Health.
2. Muthu, V.K. (2014) A Short Book of Public Health.
3. Detels, R. (2017) Oxford Textbook of Public Health (6th edition).
4. Gibney, M.J. (2013) Public Health Nutrition.
5. Wong, K.V. (2017) Nutrition, Health and Disease.

Semester	Course	Course Title	Credit
III/ IV	**SEC-3**	**Dairy Production and Technology**	Theory:04

About the course

The course is designed to give an account of different breeds of dairy cattle, their characteristics and performance, the factors affecting their health and the technologies that help artificial insemination and genomic testing.

Learning outcomes

After successfully completing the course, the students will be able to

- learn about protein metabolism and nutritional recommendations for various stages of the lactating mother and diet preparation techniques.
- acquire the skills to manage a dairy farm or to start one with adequate inputs.

Unit-I: Planning and maintaining desired cattle breeds 15 Lectures

History and future of Dairy Industry, Major dairy markets of the world, Distribution map of mdairy farming areas/ major milk producing regions in India. Dairy Products and their nutritive value. Milk, cheese, yoghurt, gluten etc; Dairy farm planning Management. Challenges in setting up a dairy farm. Environment and facilities: Expertise, Animals Dairy herd health and production; Managing Dairy Cattle. Breed selection: Breeds of cattle and buffalo, Native cow varieties, Indian exotic breeds their popularity and performance; Forage Production and Pasture Management. Nutritional requirements, Sources of feed: Temperate and tropical grasses. Feed composition– nutrients for milk production, Water Energy, Protein, Fibre, Energy and digestibility, Vitamins.

Unit-II: Housing and maternity management 13 Lectures

Housing of Dairy Cattle. Dairy and shed design. Cooling strategies, Cow comfort Management; Cleaning Management. Animal signs Management. Dairy herd Management and growth; Cow health and reproductive performance. Breeding Dairy Cattle. Artificial insemination and conception; Maternity management, The Lactation Cycle. Calf management, Calf diseases; Common management procedures. Vaccination, dehorning, weaning etc.

Unit-III: Milk products management **11 Lectures**

Milk products: Cheese, yogurt, gluten etc. Milking Management. Gathering cow for milking; Milking machines for smallholders; cleaning and sanitizing dairy equipment; Milking procedure. Dry cow therapy; Milk filtration Management. Milking Hygiene; Post-harvest milk quality.

Unit-IV: Business prospects, Biosecurity **13 Lectures**

Dairy business profit strategies. Common disorders in Dairy Cattle; Managing Dairy Facilities for sick and lame cows. Mastitis, metabolic disorders, hypermagnesemia, ketosis and fatty liver, Ruminal acidosis, metritis; Hoof management.Manure handling. Cow Longevity; Dairy buffalo Production Management, Biosecurity; Farm level economics affecting productivity and profitability.

Recommended readings

1. Klaus, A. J. (2015) Dairy Farming: The Beautiful Way
2. Leitch, A. (2018) The Dairy Farm: Dairy Cattle Methods, and Dairy Farm Management

Semester	Course	Course Title	Credit
III/ IV	**SEC-4**	**Computer Applications**	Theory:04

About the course

The course is designed to give an insight into the basic computer applications besides giving an idea about the internet resources, multimedia, citations and bibliography management ans important software.

Learning outcomes

After the completion of this course the learner will be able to:

- Apply the basic operations of spreadsheet applications
- Recognize advanced resources for accessing scholarly literature from internet
- Utilize bibliography management software while typing and downloading citations
- Operate various software resources with advanced functions and its open office substitutes.

Unit-I: About PC, operating system and software **14 Lectures**

Introduction to PC and Window operating system, application software (Windows, MS word). Introduction of spreadsheet (MS Excel): application, formula and functions; performing basic statistics using spreadsheet applications; creating basic graphs using spreadsheet applications, logical (Boolean) operators. MS Power point application and functions, Microphotography and scale calibration and digital image processing.

Unit-II: Computer Networking **11 Lectures**

Introduction to computer network, data communication, components of data communication, data transmission mode, data communication measurement, LAN, MAN, WAN, wireless LAN, internet, intranet, extranet; www, telnet, ftp, e-mail, social networks, search engines.

Unit-III: Internet Resources and Multimedia **14**

Lectures

The Internet and Multimedia: Internet History. Multimedia on the Web. Designing for the World Wide Web: Developing for the Web, Text and pictures for the web page. Video Conferencing, e-Commerce, m-Commerce, VOIP, blogs.

Unit-IV: Bibliography management **13 Lectures**

Advanced Google search operators. Introduction to Google Scholar and accessing scholarly literature from Internet. Introducing a bibliography management software (for e.g. Endnote), Styles and Templates, making bibliography style as per journal format; Citing while typing in the office application.

Recommended readings

1. User manual and online user manual of respective softwares for the most updated content
2. Published books are not recommended as versions keep on updating very frequently; therefore, it is not easy to follow.

Semester	Course	Course Title	Credit
III/ IV	**SEC-5**	**Biofertilizers**	Theory:04

About the course

The course will provide information on useful microbes such as Cyanobacteria, Mycorrhiza and their role in manufacture of biofertilizers. Use of microbes in production of bioinsecticides and the methods of Organic farming, Recycling, Vermicomposting etc. will also be discussed.

Learning outcomes:

On the completion of this course, the students will be able to;

- Develop their understanding on the concept of bio-fertilizer
- Identify the different forms of biofertilizers and their uses
- Compare between the Green manuring and organic fertilizers
- Develop the integrated management for better crop production by using both nitrogenous and phosphate bio fertilizers and vesicular arbuscular mycorrhizal (VAM).
- Interpret and explain the components, patterns, and processes of bacteria for growth in crop production

Unit I: **Microbes as fertilizers** **15 Lectures**

General account about the microbes used as biofertilizer – Rhizobium – isolation, identification, inoculum production and field application, legume/pulses plants. carrier based inoculants, Actinorrhizal symbiosis. *Azospirillum:* isolation and mass multiplication – carrier based inoculant, associative effect of different microorganisms. *Azotobacter*: classification, characteristics – crop response to *Azotobacter* inoculum, maintenance and mass multiplication.

Unit II: **Blue green algae, Phosphate solubilising microbes** **12 Lectures**

Cyanobacteria (blue green algae), *Azolla* and *Anabaena azollae* association, nitrogen fixation, factors affecting growth, blue green algae and *Azolla* in rice cultivation. Phosphate solubilizing microbes - Isolation, characterization, mass inoculum production, field application.

Unit III: **Mycorrhizal effect on plant growth** **12 Lectures**

General account of Mycorrhizae; Types of mycorrhizae: ectomycorrhizae and endomycorrhizae; Types of associations, occurrence and distribution, Nutrition, growth and yield – colonization of vesicular-arbuscular mycorrhiza (VAM)– isolation and inoculums; production of VAM and its influence on growth and yield of crop plants.

Unit IV: Microbial use in bioinsecticides and biocompost **13 Lectures**

Microbes used as bioinsecticides and their merits over synthetic pesticides, *Bacillus thuringiensis*, production and Field application. Viruses – cultivation and field applications. Organic farming – Green manuring and organic fertilizers, Recycling of bio-degradable wastes: municipal, agricultural and Industrial wastes. Methods of making biocompost; Procedure of vermicomposting and field application.

Recommended readings

1. Dubey, R.C. (2005). A Text book of Biotechnology S.Chand & Co, New Delhi.
2. John Jothi Prakash, E. (2004). Outlines of Plant Biotechnology. Emkay Publication, New Delhi.
3. Kumaresan, V.(2005). Biotechnology, Saras Publications, New Delhi.
4. NIIR Board. (2012). The complete Technology Book on Biofertilizer and organic farming. 2nd Edition. NIIR Project Consultancy Services.
5. Sathe, T.V. (2004) Vermiculture and Organic Farming. Daya publishers.
6. Subba Rao, N.S. (2017). Biofertilizers in Agriculture and Forestry. Fourth Edition. Medtech.
7. Vayas, S.C.; Vayas, S. and Modi, H.A. (1998). Bio-fertilizers and organic Farming Akta Prakashan, Nadiad

Semester	Course	Course Title	Credit
III/ IV	**SEC-6**	**Environmental impact analysis**	Theory:04

About the course

The course provides information on Environmental Impact Assessments (EIA) that helps in the anticipation and minimization of development's negative effects. This course enlightens about effective monitoring and controlling the trans-boundary pollution.

Learning outcomes

After completing this course the learner will be able to;

- Have critical understanding of environmental impact
- Learn important steps of EIA process
- Interpret the environmental appraisal and procedures in India.

Unit I: Origin and Development 13 Lectures

Purpose and aim, core values and principles, History of EIA development, Environmental Management Plan, Environmental Impact Statement, Scope of EIA in planning a Project and its mplementation.

Unit II: EIA Process 16 Lectures

Assessment process of Environmental Impact: Screening, Scoping, Baseline data, Impact Identification, Prediction, Evaluation and Mitigation, Appendices and Forms of Application, Techniques of Assessment-Cost-benefit Analysis, Matrices, Checklist, Overlays, EIA Document.

Unit III: Main participants in EIA Process 11 Lectures

Roles of Project proponents and environmental consultants, Roles of the State Pollution Control Boards (*PCBs*) /Pollution Control Committee (PCCs), Impact Assessment Act (IAA). Public participation.

Unit IV: Environmental Appraisal and Procedures in India and EIA 12 Lectures

Environmental Audit of different environmental resources, Risk Analysis, Strategic environmental assessment, ecological impact assessment: legislation. Impact on Environmental component: air, noise, water, land, biological, social and environmental factors.

Recommended readings

1. Kulkarni V and Ramachandra TV, (2006). Environmental Management, Capital Pub. Co. New Delhi.
2. Petts, J. (2005) Handbook of Environmental Impact Assessment- Volume 1 and 2. Blackwell Publishers, UK.
3. Glasson, J. Therivel, R. and Chadwick, (2006) A. Introduction to Environmental Impact Assessment. Routledge, London.
4. Canter, W. L. (1995) Environmental Impact Assessment, McGraw-Hill Science/ Engineering/ Math, New York;
5. Morris, P. and Therivel, R. (1995) Methods of Environmental Impact Assessment, UCL Press, London;
6. Petts, J. (1999) (ed) Handbook of Environmental Impact Assessment, volume 1 and 2, Blackwell Science, Oxford;
7. Therivel, R. and Partidario, M.R. (1996) (eds) The Practice of Strategic Environmental Assessment, Earthscan, London;
8. Vanclay, F. and Bronstein, D.A. (1995) (eds) Environmental and Social Impact Assessment, Wiley & Sons, Chichester.

Semester	Course	Course Title	Credit
III/ IV	**SEC-7**	**Insect Pest, Vector Biology and Management**	Theory:04

About the course

The course provides an insight into the types of insect pests and vectors and the factors driving their spread. It also enlightens about the methods used to bring down their population below the threshold for a better management.

Learning outcomes

After completing this course the students will be able to

- Identify the types of insect pests particularly the most common one.
- Know the methods of sampling of the pests.
- Understand the mode of action of nematicides and the consequences of their use.
- Understand the effective way of insect pest management strategy.

UNIT I : Background to Insect Pests and Vectors **13 Lectures**

Insect pests and vectors of plant and animal diseases. Pest status: (major, minor, occasional, migrant). Human practices and pest occurrence. Disease outbreaks. Population dynamics of pest. Density dependent and independent factors affecting pest and vector population. Allocation of sampling units. Sampling and monitoring methods of arthropod pests.

UNIT II: Approaches to Insect Pest and Vector Management **13 Lectures**

Insecticides. Types of insecticides, Formulation; Toxicity and safety. Application of insecticides: Droplet size; Application equipment Problems associated with using insecticides. Environmental and cultural control (Irrigation, Fertilizer, Sanitation. Alternate hosts, Multiple and intercropping, Separation in time and space, Crop geometry). Host resistance: Basis for resistance, mechanisms of resistance.

UNIT III: Approaches to Insect Pest and Vector Management **14 Lectures**

Biocontrol agents: Predators, Parasitoids, Parasites. Pathogens: fungi, viruses, bacteria, microsporidia, nematodes, arthropods. Transmission of pathogens. Area-wise management. Techniques of biocontrol: constraints and reasons for failure of biocontrol. Use of pheromones/ allelochemicals in pest management; Mating disruption/confusion, Alarm pheromones and oviposition deterrents; repellents. Exclusion and barriers, Traps. Physical disturbance. Use of Larvivorous Fish and plants in vector control.

UNIT IV: Legislation and other alternatives **12 Lectures**

Exclusion and routes of entry. Risk assessment; Damage thresholds Forecasting; Increasing agroecosystem resistance Legislation for Pesticide use; Effects of regulation; Genetically modified organisms. New concepts and practices. Integrated vector management.

The integrated control/ IPM; Constraints towards IPM adoption. Eradication versus management concept.

Recommended readings

1. Van Emden, H.F. and M.W. Service. (2004) Pest and Vector Control. Cambridge University Press.
2. Cameron, M. & Lorenz, L. (2013) Biological and Environmental Control of Disease Vectors. CABI, UK
3. Chaterjee, K.D. (1981) Parasitology : Protozoology and Helminththology : Introduction to Clinical Medicine.(12th .Edition) Chaterjee Medical Publishers
4. Mullen, G. and Durden L. (2009). Medical and veterinary entomology, Academic press, London.
5. Kochchar, S.K. (2009). A Text Book of Parasitology. Wisdom Press

Semester	Course	Course Title	Credit
III/ IV	**SEC-8**	**Preventive medicine**	Theory:04

About the course

The course focuses on types of disease and injury prevention and control. The course also gives an account of the health and disease surveillance, health interventions, and implementation of disease prevention strategies.

Learning outcomes

After completing this course the learners will be able to

- Develop and implement public health interventions
- Engage with health systems and public health initiatives.
- Increase their skills, attitudes and knowledge towards causes of diseases
- Apply knowledge of the principles of disease, injury prevention and control
- Prepare expert educational outreach lectures and presentations
- Increase their skills towards knowledge of community health improvement

Unit-I: Human health and its determinants **13 Lectures**

Definition of health; concepts of health – Biomedical, ecological, psychological and holistic. Dimensions of health – physical, mental, social, spiritual, emotional and vocational. Determinants of health – biological, behavioural, environmental, socio-economic and health services.

Unit-II: Man and Medicine: Towards Health for all **11 Lectures**

History of scientific medicine. Concept of well being – Standard of living, level of living and quality of life..Theory of diseases. Communicable and non communicable diseases. Epidemiology, Etiology, Pathogenesis, Disease control/elimination/eradication. Role of Genetics in Health and Disease, Levels of Prevention. Types of Epidemiology, Uses of Epidemiology

Unit-III: Concept of Health and Diseases **14 Lectures**

Prevention and Control of Communicable Diseases, like Malaria, Cholera, Tuberculosis, Leprosy, Diarrhoea, ARI, Poliomyelitis, Viral Hepatitis, Measles, Dengue, Rabies, AIDS, etc. Non communicable diseases, like coronary heart disease, hypertension, diabetes mellitus, cancers, etc. Occupational disorders like, pneumo-coniosis, hearing loss, accidents, dermatosis, etc.

Unit-IV: Health promotion and awareness programmes **14 Lectures**

Modes of Interventions: health promotion, specific protection Ecology of health and right to health, early diagnosis and treatment, disability limitations and rehabilitations. Health programmes in India – NVBDCP, NLEP, NTP, National AIDS control programme, Immunization programme; other awareness programmes.

Reference

1.Park, K. (2017) Park's Textbook of Preventive and Social Medicine.

2.Mahajan, K. (2013) Principles of Preventive and Social Medicine.

3.Holland, W.W., Detels, R. & Knox, G. (2002) Oxford text book of Public Health (4^{th} edition).

Semester	Course	Course Title	Credit
III/ IV	**SEC-9**	**Ornamental Freshwater fish production**	Theory:04

About the course

To make the students aware of the vast potentials involved in ornamental fish farming and trading besides making them learn the diseases in fishes and other constraints in their culturing.

Learning outcomes

After completing this course the learners will be able to

- To learn the scientific method of setting an aquarium
- To learn the culture breeding and marketing techniques of common indigenous ornamental fishes

Unit I: Designing and preparation of aquaria with all accessories **13 Lectures**

Importance and history of aquarium fish keeping. Design and construction of aquaria: aquarium fabrication- shape, size, volume, type of glass tank, cutting of glass, preparation of glass tank, strengthening and supporting of tank, fitting of tanks into room settings; aquarium floor setting – type and size of pebbles, gravels, granites used for bed setting and its advantages. Filters- biological, chemical and mechanical. Aquarium accessories like aerators, decorative, lighting, heating and feeding trays. Water quality management in aquarium systems – sources of water, containers, storage, temperature, pH, dissolved carbon dioxide, ammonia, hardness, turbidity and ozone in aquarium. Aquarium plants: Uses of aquarium plants, different varieties of plants like submerged plants (tubers, rooted plants, cutting plants) and emerged plants.

Unit II: Common fresh water ornamental fishes. **13 Lectures**

Fresh water ornamental fishes : Common ornamental fishes- indigenous and exotic species; Identification and biology of the common ornamental fishes. *Cyprinus carpio* (koi carp), *Molliensia sphenops* (black molly lyre tail), *Poecilia reticulata* (guppy), *Poecilia latipinna*, *Xiphophorous helleri* (red sword tail) *Xiphophorous maculates* (red platy) *Pterophyllum scalare altum* (angel fish) *Carassius auratus* (red oranda*) Betta splendens* (Siamese fighting fish) *Trichogaster leeri* (pearl gourami). Live bearers and egg layers. Sexual dimorphism in ornamental fishes.

Unit III: Important indigenous ornamental fishes. **13 Lectures**

Indigenous ornamental fishes - Common indigenous ornamental fishes. Identification and biology of the common ornamental fishes. Cyprinids :*Puntius denisonii* (red line torpedo fish),*Puntius fasciatus* (melan barb), *Puntius filamentosus* (Indian tiger barb), *Puntius curmuca* (red tailed silver shark), *Danio malabaricus* (Malabar danio); Loaches: *Nemacheilus triangularis* (Zodiac loach), *Lepidocephalus thermalis* (Malabar loach); Cichlids: *Etroplus maculatus* (yellow and orange chromides), *E . suratensis* (pearl spot), Anabantids: *Anabas testudineus* (climbing perch) and Catfishes : *Horabagrus brachysoma* (Yellowish catfish), *H . nigricollaris* (White collared imperial catfish).

Unit IV: Management of the brood stock **13 Lectures**

Breeding and rearing of common ornamental fishes. Conditions for breeding- pH, temperature and sex ratio. Brood stock management- selection of brooders, maintenance and management of brood stocks. Selective breeding and hybridization techniques. Induced breeding. Colour enhancement techniques. Food and feeding - live feed and formulated feed. Preparation and culture of live feed (Artemia, Infusoria, Spirulina). Control of algal growth, snails and other predators. Common disease of ornamental aquarium fishes - their causative agents - virus, bacteria, fungi, protozoa and nematode; symptoms, treatment and prophylactic measures.

Recommended readings

1. Axelord, H.R. (1967). Breeding aquarium fishes, T F H Publications.
2. Mills, D. (1981). Aquarium Fishes, Arco publishing.
3. Mills, D. and Vevers, G. (1982). The Practical encyclopedia of fresh water ,Tropical Aquarium fishes, Salamander Books limited, London.
4. Gahlawat, S.K., *et.al*. (2007). Manual of experimental Ichthyology, Daya publishing House, Delhi.
5. Brunner, G. (1973). Aquarium plants, T F H Publications, Inc. Ltd., Hongkong.
6. Hansen, J. (1979). Making your own aquarium, Bell and Hyman Ltd., London.
7. Lovell, T. (1998). Nutrition and feeding of fish second Ed. Kluwer Academic publishers.
8. Talwar, P.K., and Jhingran, A.G. (1991). Inland fishes Oxford and IBH Publishing Co. PVT LTD,New Delhi.

Semester	Course	Course Title	Credit
III/ IV	**SEC-10**	**Aquaculture**	Theory:04

About the course

This course will give the students an understanding of the principles of aquaculture, including production systems, water quality, nutrition, spawning, larval culture and culture methodologies with special reference to fish, and prawn. The course will include an opportunity to conduct hands-on activities related to culture and husbandry of animals

Learning outcomes

After completing this course the learners will be able to

- understand the aquaculture systems
- Understand conditioning factors and how they can be manipulated
- Describe water depuration mechanisms
- Understand the environmental impacts of aquaculture

Unit I : Freshwater aquaculture systems — 13 Lectures

Aquaculture concept, Culture systems: Freshwater prawn culture, fish culture in paddy fields, Brackish water culture, Mariculture: Oyster culture, Crab culture, Lobster culture, mussel culture, culture of Eels, Culture of aquatic weeds. Composite fish culture: Definition and various patterns. Mixed fish farming in India. Techniques of composite culture. Culture of buffalo fish ..Culture of Catfishes. Culture of miscellaneous fishes. Cray fish culture.

Unit II: Preparation and management of fish culture ponds — 13 Lectures

Nursery ponds. Predatory and Weed fishes and their control. Fish toxicants. Fertilization. Aquatic insects and their control. Fish food organisms and their production. Supplementary feeding. Transport of fish seed and Brood fish. Causes of mortality in transport. Methods for packaging and transport. Open systems. Closed systems. Use of chemicals in live fish transport. Anesthetic drugs. Antiseptics and Antibiotics.

Unit III: Fish pathology — 13 Lectures

Parasitic infections. Fungus infections. Protozoan diseases.suryodata; Worm diseases. Non parasitic diseases. Rearing ponds, Stocking ponds. Fish breeding: Natural and artificial. Harvesting: Fishing techniques, preservation & processing of fish. Fresh water prawn culture. Introduction. Breeding characteristics. Juvenile prawn migration. Seasonal & regional distribution of seeds. Identification of juveniles. Controlled breeding. Culture: Ponds, Monoculture. Mixed culture.

Unit IV: Technologies in Fisheries development **13 Lectures**

Role of hard water in culture of *Macrobrachium* species. Fertilization & feeds. Pearl culture: Introduction, Pearl producing mollusks, pearl formation, collection of oysters, Rearing of oysters, insertion of nucleus, harvesting of pearls, composition & quality of pearl. Recirculation technology, Geographic Information System (GIS) technology, passive Acoustics in fisheries, Use of Information Communication Technology (lCT) in fishes: production aspects, marketing aspects.

Recommended readings

I. Jingran, V. G. (1983) Fish and fisheries of India , Hindustan pub. corp. New Delhi.

2. Hute, M. and Kahn, H. (2000) Textbook of fish culture, Blackwell Scientific Publication, Australia.

3. Srinivasulu, M., Reddy, K.R.S., Rao, S. (1999) Text book of Aquaculture, Discovery Publishing House New Delhi.

4. Yawn Mehta, Fisheries & Aquaculture Biotechnology (2011) Campus Books International, Prahalad street, Ansari Road, Durga Ganj, New Delhi.

Semester	Course		Credit
III/ IV	**SEC-11**	**Toxicology**	Theory:04

About the course

This course is focused on theoretical and applied knowledge on the effects of chemical substances on human health. The students will also get introduced to the toxicological analysis and the signs and symptoms of important toxic syndromes. The students will also study the basic toxicokinetic principles and metabolic systems to elucidate mechanisms of toxicity induced by xenobiotic compounds.

Learning outcomes

After completing this course the students will be able to

- learn basic principles of signaling pathways and mechanisms of cell death
- understand gene-environment interactions
- examine the application how xenobiotics disrupt normal cellular processes of genomics, proteomics, and metabolomics data
- understand mechanisms of systemic and organ toxicity induced by xenobiotics; and 5) learn how to analyze and interpret complex data sets in toxicological research and deliver a scientific presentation.
- use clinical and laboratory findings in the treatment of acute toxic exposures

Unit I: **Basic Concept of Toxicology** — **12 Lectures**

Introduction of toxicology, history of toxicology, definition of toxicology, definition of poison, definition of toxicity and classification of toxicants. Mode of action of toxic agents.

Unit II: **Xenobiotics** — **14 Lectures**

Introduction,Important of xenobiotics concerned to Human health, absorption of xenobiotics, distribution of xenobiotics, accumulation of xenobiotics, elimination, biotransformation and excretion. Adverse effects of xenobiotics through Biological Magnification and Biotransformation, mechanism of Xenobiotic Translocation, Membrane permeability and mechanism of chemical transfer,

Unit III: **Pesticides and Heavy Metal Toxicity** — **14 Lectures**

Pesticides and their toxicological effects. Classification of Pesticides, Insecticides, Mode of action of Insecticide. Heavy Metal Toxicity: Introduction, dispersion, general principal of metal toxicity, sources, toxic metals and their toxicity. Arsenic, Alumunium, Cadmium (Itai-Itai disaster), Chromium Lead, Mercury, Manganese, Zinc and Nickel.

Unit IV: **Evaluation of toxicity.** — **12 Lectures**

Acute subAcute and chronic assays LD_{50}, LC_{50} ,NOEL. Maintenance and general handling of animals for toxicological laboratory. Ecotoxicology, clinical toxicology, occupational and nanotoxicology.

Recommended readings

1. Williams, P.L.; James, R. C. Roberts, S.M. (2003) Principles of Toxicology: Environmental and Industrial Applications, John Wiley & Sons, Inc.
2. Klaassen, C. (2007) Casarett and Doull's Toxicology The basic science of poisons – McGraw-Hill.
3. Duffs, J. and Worth, H. (2006) Fundamental Toxicology, RSC Publishing.

Semester	Course	Course Title	Credit
III/ IV	**SEC-12**	**Beekeeping**	Theory:04

About the course

This course tells the students what tools and equipment will be needed, the main activities in the beekeepers year, the laws and by laws governing keeping bees; discover the principles of sustainable beekeeping and how these principles can guide your beekeeping into an enduring practice.

Learning outcomes

Upon successful completion of this course, the student should be able to:

- Explain what are the prerequisite to get started in beekeeping
- Describe the laws around beekeeping in Vancouver
- Discuss the responsibilities of urban beekeepers
- Identify where to purchase equipment and demonstrate how to assemble it
- Name and identify major parts of the honeybee such as the stinger or mandibular parts
- Describe bee biology and anatomy from the perspective of managing bees
- Describe the importance of wax and identify what to look for in comb during hive inspections

Unit I: **Introduction to Apiculture** **12 Lectures**

History of Bees and Beekeeping, Systematics, Bee species, Bee morphology, Colony organization, Polymorphism, Caste system, Division of labour, Bee flora, Foraging and Honey flow periods.

Unit II: **Bee keeping as an occupation** **13 Lectures**

Extent of Beekeeping in Maharashtra and India, Limitations on the development of beekeeping, Advantages of extensive Beekeeping. Beekeeping equipments: Bee box and tools and initiation into keeping a colony, the future of beekeeping.

Unit III: **The first step in beekeeping** **14 Lectures**

Purchase of a colony, the Apiary site, how to manage a colony, the manipulation of a colony. Bee products: Honey, Bees wax, Pollens, Royal Jelly, Propolis and Bee venom. taking care of bee diseases and enemies. Establishment of a colony. Bee flora and planned pollination services.

Unit IV: **Beekeeping techniques and Apiary management** **13 Lectures**

Routine management, Seasonal management, Migratory beekeeping, Harvesting and marketing of bee products. Important Institutions pertinent to Apiculture: National Bee Board, Bee research and Training Institute, Apiaries. Economics and extension of Bee keeping.

Recommended readings

1. Abrol , D. P. (1997) Bees and Beekeeping. Kalyani Publisher, New Delhi.
2. Abrol, D. P. (2010) A Comprehensive guide to Bees and Beekeeping. Scientific Publisher, New Delhi.
3. Withhead, S. B. (2010) Honey bees and their management Axis books Publisher, Jodhpur.
4. Nagaraja, N. and Rajagopal , D. (2013) Honey bees: Diseases, Parasites, Pests, Predator and their management. M.J.P Publisher, Chennai.
5. Dharamsing and Singh, D. P. A Handbook of Beekeeping, Agrobios India (Publisher), Jodhpur.

Semester	Course	Course Title	Credit
III/ IV	**SEC-13**	**Sericulture**	Theory:04

About the course

The course gives insight into the principles of sustainable sericulture and how these principles can guide your silkmoth rearing into an enduring practice. The students will know about the laws and by laws governing keeping silkmoth.

Learning outcomes

Upon successful completion of this course, the student should be able to:

- Generation of skilled man power in the field of sericulture,
- To impart training in extension management and transfer of technology,
- To impart training in Post Cocoon Technology, and
- To provide field exposure

Unit I: Silkworm distribution and races **12 Lectures**

The silkworms. Its morphological characteristics. Distribution and types of races. Exotic and indigenous races of silkworm. World silk production World map and silk road, spread of Sericulture to Europe, South Korea, Japan, India and other countries. Sericultural practices in tropical and temperate climate.

Unit II: Biology of silkworm **13 Lectures**

Mulberry and non-mulberry Sericulture. Biology of silkworm. Selection of mulberry variety and establishment of mulberry garden, Rearing house and rearing appliances. Silkworm rearing technology: Early age and Late age rearing Selection of silkworm races/breeds for rearing. Incubation- definition, requirement of environmental conditions, incubation devices; identification of stages of development; black boxing and its importance.

Unit III: Diseases of silk worm and prevention and control **14 Lectures**

Diseases of silkworm**.** Disinfectants: Formalin, bleaching powder RKO. Types of mountages, Spinning, harvesting and storage of cocoons. Introduction; classification of silkworm diseases. Protozoan disease: symptomatology due to *Nosema bombycis* infection, source, mode of infection and transmission, cross infectivity, prevention and control. Bacterial, Viral, Fungal diseases: causative agents, symptoms, transmission prevention and control.

Unit IV: Prospects of Sericulture in India **13 Lectures**

Sericulture Types- natural and synthetic fibres- types of silk produced in India; Importance of mulberry silk. Silk industry in different states, employment, potential in mulberry and non-mulberry sericulture. Employment generation in sericulture: Role of women in sericulture.
Sericultural practices in rain-fed and irrigated conditions; traditional and non-traditional areas. Sericulture organization in India; role of state departments of Sericulture, Central Silk Board, Universities and NGOs in Sericulture development
.

Recommended readings

1. Manual on sericulture (1976). Rome : Food and Agriculture Organization of the United Nations, Agricultural Services Division.
2. Ullal, S.R. and . Narasimhanna, M.N. (1987) Handbook of Practical Sericulture: CSB, Bangalore
3. Silkworm Rearing and Disease of Silkworm (1956) Ptd. By Director of Ptg., Stn. & Pub. Govt. Press, Bangalore
4. Jolly, M. S. (1986) Appropriate Sericultural Techniques; Ed., Director, CSR & TI, Mysore.
5. Handbook of Silkworm Rearing: Agriculture and Technical Manual-1 (1972) Fuzi Pub. Co. Ltd., Tokyo, Japan.
6. Narasimhanna, M. N. (1988) Manual of Silkworm Egg Production;, CSB, Bangalore.
7. Sengupta, K. (1989) A Guide for Bivoltine Sericulture. CSR & TI, Mysore.

Semester	Course	Course Title	Credit
III/ IV	**SEC-14**	**Ecotourism**	Theory:04

About the course

This course is designed to provide students with an understanding of the management and planning of ecotourism opportunities. The course will give students to the concept of ecotourism and its economic, cultural and environmental impacts at different scales. Students will learn the methods through which ecotourism can be marketed and managed, together with its potential adverse impacts.

Learning outcomes

Upon successful completion of this course, the student should be able to:

- identify and manage for ecological impacts to soil, water, vegetation, and wildlife resulting from recreation and tourism development;
- understand ecological impacts and ecotourism management approaches in a variety of ecosystems under diverse landowners;
- ability to analyze the environmental and social consequences of ecotourism management strategies and decisions;
- understand management tools to reduce visitor related impacts that occur in ecotourism areas (impacts of outdoor recreation include impacts to soil, vegetation, water, wildlife, air, soundscape, night sky, historical/cultural resources, visitor experiences, and facilities/services).

Unit I: Baseline information about Ecotourism — 13 Lectures

History of ecotourism and its definitions. Types of Tourism: Extreme tourism Mass tourism. Why is mass tourism NOT eco-friendly? Evolution and characteristics of ecotourism, relevance of responsible tourism. World Ecotourism Summit- policies and formulations How an ecotourism development can benefit future generations. Ecotourism as a tool of capacity building and conservation.

Unit II: Ecotourism as an industry — 13 Lectures

Ecotourism as a growth sector within the tourism industry. Tourist resorts. Environmental, socio-cultural and economic impacts of ecotourism. Viewpoints on tourism industry and major constituents, Tourism organizations – international, national, state level and private sector, Importance of tourism statistics. Tourism industry in India, Ecotourism in Kerala-possibilities and problems.

Unit III: Management functions and practices in tourism — 12 Lectures

Tourism policies and planning, Involvement of local bodies and officials in tourism, Coordination between tourists and hosts, Tourism products and operation, Tourist sites and attractions. Managing personnel in tourism, Managerial practices in tourism, Tourism services and management, Seasonality and destination in tourism, Preparation of maps and charts.

Unit IV: Marketing ecotourism **13 Lectures**

Tourism marketing- definition, concepts and features Advertising and publicity in tourism Role of media in tourism, Tourism writing. Communication skills and tourism Ecotourism and competing resource users. International and domestic tourism markets, Marketing research and analysis, Tourism forecasting and use of technology in tourism marketing, Airlines, Travel Agency, hotel accommodation, tour packages marketing etc.

Recommended readings

1. Mowforth, M., & Munt, I. (2009). Tourism and sustainability (3rd Edition). London, UK: Routledge.

2. Newsome, D., Moore, S.A., & Dowling, R.K (2002). Natural area tourism. Bristol, UK: Channel View. (Publications.

3. Weaver, D. (2008). Ecotourism (2nd Edition). Hoboken, NJ: JS Wiley. Staff : Dr Julian Clifton

9. Teaching-Learning Process (may be expanded keeping in view needs and outcomes of the subject)

As programme of study in Zoology is designed to encourage the acquisition of disciplinary/subject knowledge, understanding and skills and academic and professional skills required for Zoology-based professions and jobs, learning experiences should be designed and implemented to foster active/participative learning. Development of practical skills will constitute an important aspect of the teaching-learning process. A variety of approaches to teaching-learning process, including lectures, seminars, tutorials, workshops, peer teaching and learning, practicum and project-based learning, field-based learning, substantial laboratory-based practical component and experiments, open-ended project work, games, technology-enabled learning, internship in industry and research establishments etc. will need to be adopted to achieve this. Problem-solving skills and higher-order skills of reasoning and analysis will be encouraged through teaching strategies.

The syllabus aims to provide this knowledge, capitalising upon the research activity and teaching expertise of the academic staff. The syllabus is also designed to develop the “analytical techniques and problem-solving skills” relevant to graduate-level employment. Students are encouraged to see themselves as producers of knowledge and collaborators in their learning experience. Lectures introduce key topics in the subject area and guide students ‘independent study. Practical will allow students to develop laboratory skills and skills in fieldwork, surveying, data handling and processing, as well as to encounter at first hand the principles introduced in the lectures. Students will also develop their own interests through self-guided research skills, as library based study and background research and project work. Seminars and small group tutorials will be used to facilitate class discussion. There have to be site visits and lectures by external specialists to provide opportunities to meet animal scientists employed in graduate roles and their employers. There will be an emphasis on the practical application of principles and the development of graduate skills will be included in subject specific units.

A teacher offer ways for the learners to take an active role, for at least a portion of the course, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate strategies and evaluating the outcomes both internal and external. A teacher has not only to instruct but also to inspire the students; he or she has to influence the life and character of his or her students, and equip them with ideas and values which will enable them to enter the national stream as worthy citizens. Teachers are supposed to do all these during the years as the students are under their contact and influence in the College. Learning technology is the broad range of communication, information and related technologies that can be used to support learning, teaching, and assessment. Blended Learning is learning that is facilitated by the effective combination of different modes of delivery, models of teaching and styles of learning and applying them in an interactively meaningful learning environment. E-Learning is the use of technology to enable people to learn anytime and anywhere. E-Learning can include training, the delivery of just-in-time information and guidance from experts. Video lectures recorded in segments, case studies, reading material, homework, and quizzes are designed in advance and made available for online streaming or download. Students are expected to watch the videos, read the assigned material, and do homework before attending class, online or face-to-face, for discussions with the instructor or a teaching assistant. Technology-enabled instructor engagement and robust learning cohorts give students the experience of learning with peers and from a teacher rather than in isolation from a book or content management system. Importantly, these new technologies allow class enrolment to scale effectively from tens or hundreds of students to thousands of students per class. Scalable online courses can be designed to fit the operational and economic needs of most degree or certificate granting enterprises to:

- Enforce and control registration and course credit, prerequisites and advisor approval.
- Secure tuition payments either before course start or before certification.
- Engage local instructors and/or teaching assistants in the delivery of the course even if the professor’s home institution is remote.

Following Active Learning Methodologies may need to implement: –

- Learning by Doing
- Concept Maps
- Brainstorming
- In class surprise quizzes and discussion –
- Combine lectures with videos and discussions –

- Process Oriented Guided Inquiry Learning (POGIL) – Flipped Classroom

Using quality scalable online courses taught by other faculty is probably even more important to the long run economic health of most institutions, though this requires a substantial change in culture. Computer supported collaborative learning (CSCL) is a pedagogical approach wherein learning takes place via social interaction using a computer or through the Internet. This kind of learning is characterized by the sharing and construction of knowledge among participants using technology as their primary means of communication or as a common resource.

10. Assessment Methods (may be expanded keeping in view the needs and outcomes of the subject)

The assessment of students' achievement in zoology will be aligned with the course/programme learning outcomes and the academic and professional skills that the programme is designed to develop. A variety of assessment methods that are appropriate within the disciplinary area of zoology will be used. The assessment strategy adopted within the BSc (Hons) Zoology aims to test subject knowledge, independent thought and skills acquisition and to provide information about candidates that will be useful to employers. Learning outcomes will be assessed using the methods as given earlier under head 8.1 on Page No. 24.

Formative assessment is provided during practical classes where students can apply knowledge from lectures as well as seek guidance on practical skills. Students are also encouraged to ask questions during lectures to clarify issues, or even develop ideas derived from lecture material. Lecturer’s will also set aside time for workshops and seminars focused on key subjects, where for example students can work in groups on one of a number of topics, present their conclusions for class based debate and receive feedback from lecturers as well as peers.

Methods of assessment need to be implemented

- Thinking critically and making judgements by Essay, Report, Journal and Book review (or article) for a particular case/situation
- Identifying problems, posing problems, defining problems, analysing data, reviewing, designing experiments, planning, applying information

- Computation, taking readings, using equipment, following laboratory procedures, following protocols, carrying out instructions
- Accessing and managing information (Researching, investigating, interpreting, organising information, reviewing and paraphrasing information, collecting data, searching and managing information sources, observing and interpreting) by project, dissertation and applied problem.
- Demonstrating knowledge and understanding by written examination, oral examination, essay and report
- Communicating (One and two-way communication; communication within a group, verbal, written and non-verbal communication. Arguing, describing, advocating, interviewing, negotiating, presenting; using specific written forms) by written presentation (essay, report, reflective paper etc.), oral presentation, group work and discussion/debate/role play

11. Keywords: Zoology, Systematics, Chordates & Non-Chordates, Developmental biology, Comparative anatomy, Physiology, Genetics, Evolution. Cell Biology, Biochemistry, Molecular biology, Ecology, Behaviour, Parasitology, Immunology, Biotechniques, Bioinformatics, Applied Zoology etc.

Expert Committee Members of Learning Outcomes based Curriculum Framework (LOCF) Zoology

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Learning Outcomes based Curriculum Framework (LOCF)

for

English as Generic Elective Undergraduate Programme

2019

ज्ञान-विज्ञान विमुक्तये

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

UGC LOCF (ENGLISH) COMMITTEE REPORT

for

(i) BA/B.Sc/B.Com under CBCS (English)

(ii) English Literature for Generic Elective (GE) for students majoring in subjects other than English and Discipline Specific Core (DSC) for students pursuing BA without any major (Honors) subject

Table of Contents

1.1 INTRODUCTION

All knowledge is constituted in language. But without proficiency in language, it is difficult to transmit knowledge. Language is imperative for the acquisition, preservation, dissemination, application and creation of knowledge. Hence, the importance of language learning cannot be overemphasized. It is also a fact that language transcends boundaries and barriers; the more proficient in communication we are, the more the world expands for us. Today, the English language is a window to the world. It is not only the most important link language between communities but also the preferred language of pedagogy, employment, information technology, trade and commerce and travel and tourism in India and the world. To this extent, it is crucial that learners are given adequate opportunities to develop language proficiency and skills in not just the basics of grammar but also in communicating effectively across a variety of situations. This is best acquired through a nuanced understanding of the language of literary texts, to start with. Given this, learners should be sensitized to the creative processes and learn to use language both critically as well as creatively. It is also essential for learners to be aware of the implications of language vis-à-vis issues such as gender, caste, class, culture, etc. and thus use language appropriately. Having considered this relationship between language and learning, the UGC-LOCF (English) committee suggests the following courses in language communication and literature that meet the learning outcomes of English for undergraduate students.

English Language Course* (SE Courses) for Undergraduate education in arts, science, and commerce

1. Basic English Communication Skills
2. Advanced English Communication Skills
3. Dictionary and Study Skills
4. Creativity Through Language
5. Appreciating Literature

(* Please see the APPENDIX 1 for Courses 1-5.)

1.2 Learning Outcomes based Curriculum Framework 2018-2019

BA/B.Sc/B.Com under CBCS English & English Literature for Generic Elective (GE) for students majoring in subjects other than English and Discipline Specific Core (DSC) for students pursuing BA without any major (Honors) subject

The UGC Committee constituted for Learning Outcomes based Curriculum Framework for BA/ B.Sc/B.Com (CBCS English) and English Literature for Generic Elective (GE) for students majoring in subjects other than English and Discipline Specific Core (DSC) for students pursuing BA without any major (Honors) subject is pleased to submit its Report.

The Committee suggests that the following global remarks may be considered by the faculty members, departments/schools, Boards of Studies in English, Institutes and Universities, while considering the recommendations for their use.

The Committee suggests the following guidelines for the consideration of Departments/BoS/Universities before considering their implementation:

i. The learning outcomes are designed to help learners understand the objectives of studying BA/BSc/BCom in English, to help learners use English Language for contemporary academic and social needs. Students develop all the four language skills which will enhance their communication abilities taking support from literary texts. Students will also learn to use language creatively and critically.

ii. It is significant to mention here that the BA/BSc/BCom CBCS English syllabus remains the point of reference for the LOCF recommendations. However, stakeholders (departments or universities or institutions) may make suitable alternations with justifications while selecting texts, finalizing objectives and organizing principles keeping in view global, national and regional contexts of analysis and appreciation.

iii. To this end, the texts mentioned in the LOCF document are indicative. Similarly, the organization of divisions/themes/genres/periods/authors/areas, etc. are specific to contexts identified in the course(s) and do not pre-empt further rethinking or selection with clear justification for the choices exercised therein.

iv. The organization of the courses/papers has been worked into semesters, wherever needed, keeping in mind the credit load in a given semester as well as the desired outcomes of the course/programme.

v. Learning outcomes may be modified by Universities/Institutions with proper justification, given that texts recommended for the course, contexts of teaching, and requirements of the stakeholders are as diverse as are regions in the country. The overarching concern of the LOCF committee in English is to have definite and justifiable course outcomes and their realization by the end of the course/programme.

vi. The Department/Institute/University is expected to encourage its faculty concerned to make suitable pedagogical innovations, in addition to teaching/learning processes suggested in the LOCF recommendations, so that the Course/Programme learning outcomes can be achieved.

vii. Students majoring in subjects other than English can use these courses **(see Appendix 2)** as part of GE (Generic Electives). B A (English) students without any Honors subject may offer these courses as part of DSC (Discipline Specific Core) courses.

viii. Courses suggested in **Appendix 1** are meant for BA/BSc/BCom students as SE (Skill Enhancement) Core and Elective Courses, where the number, weightage and credit load will be determined by Universities/Institutions in conformity with the recommendations given hereunder.

The present century has increasingly realised the integrality of all elements in the universe and the interrelatedness of lives in all forms. Tim Cook speaks about maintaining balance between science and the humanities:

If science is a search in the darkness, then the humanities are a candle that shows where we have been and the danger that lies ahead. It is technology married with liberal arts, married with the humanities that make our hearts sing.

The function of literature is to bring the questions of values—human and literary—into the frame.

Literariness is the ability of literature to attract attention to itself through what is clearly a special use of language. As a system of knowledge, literature is said to provide pleasure first and knowledge thereafter. Therein lies its value in being pleasant. Thereafter, the important thing is to know what literature is valued for. Literature is known for what it stands or its commitment. It also celebrates life in all forms and stands for values of life by representing—and often defending—the weak, the poor, the exploited, the vulnerable and the voiceless. In a way, literary values are values of life. The ultimate learning outcomes of literary studies is manifest in the form of acquiring linguistic and communicative competence to understand and express these values.

Accordingly, English language learning curricula have evolved over a period of time in India. From its Anglo-centric core, it has moved to the educated Indian variant of English with national and international intelligibility.

The present phase in English language learning fulfils the needs of learners in equipping them to face the vicissitudes of life. Its acceptance lies in its ability to enrich the users' engagement with local and global realties. Clearly, the users of English remain sensitive to different kinds of human experiences, both lived and imagined, and their manifestations in linguistic terms without glossing over the core attributes of life and living, that is, human values. To this end, it is necessary for English Studies to recognize and respect differences in and around the world and transcend binaries.

The LOCF for English is prepared on the contours and curricular structure provided by the UGC, and may be modified without sacrificing the spirit of CBCS and LOCF.

Keeping in mind the above aspects of BA English literature learning, the following courses have been prepared by the LOCF Committee:

English Literature* for DSC/GE for students majoring in subjects other than English *or Students doing BA without any Honors subject*

1. Introduction to Literature
2. British Literature
3. Modern Indian Literature
4. New Literatures in English

(* Please see the APPENDIX 2 for Courses 1-4.)

1.3 GRADUATE ATTRIBUTES

Disciplinary Knowledge:

a) Ability to understand, speak, read and write English both at the basic and advanced levels.

b) ability to understand and engage texts with various linguistic, critical and creative concepts and categories

c) ability to read texts closely, paying attention to linguistic and stylistic variations and innovations and also exploring themes, generic conventions and historical contexts

d) ability to understand linguistic/pragmatic frameworks to appreciate literary texts and language use

e) ability to locate and engage with relevant scholarly works in order to develop one's own critical position and present views coherently and persuasively

f) ability to situate one's own reading in terms of society, religion, caste, region, gender, and politics

g) ability to understand the world, to think critically and clearly about the local and the global through a reading of literatures in translation and in the original, to be a located Indian citizen of the world

h) ability to see and respect difference and to transcend binaries

Communication Skills:

a) ability to speak and write clearly in standard, academic English

b) ability to listen to and read carefully various viewpoints and engage with them.

c) ability to use critical concepts and categories with clarity

Critical Thinking:

a) ability to read and analyse texts

b) ability to place texts in historical contexts and be sensitive to their social relevance

c) ability to substantiate critical readings of literary texts in order to persuade others

Problem Solving:

a) ability to cope with complex language use

b) ability to read any unfamiliar literary and non-literary texts

Analytical Reasoning:

a) ability to evaluate the strengths and weaknesses in a literary text

b) ability to substantiate one's argument through an enhanced critical and communicative ability

Research-Related Skills:

a) ability to problematize and formulate research questions, and to identify and consult relevant sources to find answers
b) ability to plan and write a research paper or assignment

Teamwork and Time Management:

a) ability to participate constructively in classroom discussions
b) ability to meet a deadline

Scientific Reasoning:

a) ability to analyse texts, evaluating ideas and literary strategies
b) ability to formulate logical and persuasive arguments

Reflective Thinking:

a) ability to locate oneself and see its influence on critical thinking and reading
b) ability to carry the implications of a text to life and vice versa

Self-directed Learning:

a) ability to work independently in terms of reading literary, non-literary and critical texts
b) ability to carry out personal research, postulate questions and search for answers

Digital Literacy:

a) ability to use digital resources for gathering information
b) ability to use digital resources for presentations

Multicultural Competence:

a) ability to engage with and understand language used in literary texts from different regions
b) ability to respect and transcend differences

Moral and Ethical Values:

a) ability to interrogate one's own ethical values, and to be aware of ethical issues
b) ability to read values inherited in literary texts *vis a vis* issues of environment, religion and spirituality, as also structures of power

Leadership Readiness:

a) ability to lead group discussions

b) ability to formulate questions for the class in literary, academic and social contexts

Life-long Learning:

a) ability to retain and build on critical reading skills
b) ability to infer, cherish and practise human values
c) ability to transfer such skills in other domains of one's life and work

1.4 QUALIFICATION DESCRIPTORS

The qualification descriptors for the programme in English shall be five learning attributes such as understanding, use, communication, expansion, and application of subject knowledge with a clear understanding of one's location. This also involves an awareness on the students' part of differences pertaining to class, caste, gender, community, region, etc. in order that they can transcend these differences with transparency of purpose and thought. The key qualification descriptor shall be clarity of communication as well as ethical and social awareness. Each student should be able to

- *Demonstrate* a coherent and systematic knowledge and understanding of the field of literary and theoretical developments in the field of English Literary and Language Studies. This would also include the student's ability to identify, speak and write about genres, forms, periods, movements and conventions of writing as well as the ability to understand and engage with literary-critical concepts, and varieties of language use for social communication.
- *Demonstrate* the ability to understand the role of literature and language in a changing world from the disciplinary perspective as well as in relation to its professional and everyday use.
- *Demonstrate* the ability to think and write clearly about one's role as a located Indian citizen of the world through a reading of literatures in English and English translation
- *Communicate* ideas, opinions and values—both literary values and values of life in all shades and shapes—in order to expand the knowledge of the subject and the language as it moves from the classroom to life at large.
- *Recognize* the scope of English language and literary studies in terms of career opportunities, employment and lifelong engagement in teaching, publishing, translation, communication, media, soft skills and other allied fields

- *Apply* subject-specific skills in language and literature to foster a larger sense of ethical and moral responsibility among fellow humans in order to see and respect differences in and among various species and life-forms and learn to transcend them.

1.5 Programme Learning Outcomes

The programme learning outcomes relating to BA/B Sc/B Com English CBCS students:

- Demonstrate a set of basic skills in literary and linguistic communication and explication of literary practices and process with clarity.
- Demonstrate a coherent and systematic knowledge of the field of English literature and Bhasha literatures translated into English, showing an understanding of the contemporary world.
- Cultivate ability to look at and evaluate the language of literary texts as a field of study and as part of the wider network of local and global culture by using digital resources.
- Display knowledge to cultivate a better understanding of values – both in the use of different language registers and literary forms and genres to arrive at transparent understanding of values of life at all stages.
- Recognize employability options in English literature and language studies programme as part of skill development and as career avenues open to graduates in today’s global world such as professional writing, translation, teaching English at different levels, mass media, journalism, aviation communication and personality development
- To enable students to develop an awareness of the linguistic-cultural richness of India as an important outcome of English literary and language studies in India

1.6 TEACHING LEARNING PROCESSS

Learning is a challenging, engaging, and enjoyable activity. Learners should be encouraged to engage in a rigorous process of learning and self-discovery by adopting a highly focused approach to education versus rote learning. Each day learners should be encouraged to focus on key areas of the course and spend time on learning the course fundamentals and their application in life and society.

In teaching and learning pedagogy, there should be a shift from domain or conclusions based approach to the experiential or process based approach.

The faculty should promote learning on a proportionate scale of 20:30:50 principle, where lectures constitute 20 percent of the delivery (Hear); visuals 30 percent of the learning methods (See); and experience 50 percent (Do). This ratio is subject to change as per the needs.

In order to achieve its objective of focused process based learning and holistic development, the Institution/University should use a variety of knowledge delivery methods:

Lectures: Lectures should be designed to provide the learners with interesting and fresh perspectives on the subject matter. Lectures should be interactive in a way that students work with their teachers to get new insights in the subject area, on which they can build their own bridges to higher learning.

Discussions: Discussions are critical components of learning, and can be used as a platform for students to be creative and critical with old and new ideas. Besides developing critiquing skills, arriving at consensus on various real life issues and discussion groups lead to innovative problem solving and, ultimately to success.

Simulations: Simulations provide students with opportunities to understand real life situations and scenarios, and solve challenges in a controlled environment or make use of them in simulating cultural experiences by locating/transposing them in new (local, regional, national and international) situations.

Case Studies: Real case studies, wherever possible, should be encouraged in order to challenge students to find creative solutions to complex problems of individual, community, society and various aspects of knowledge domain concerned.

Role Play: Assuming various roles, as in real life, is the key to understanding and learning. Students are challenged to make strategic decisions through role-plays, and to analyse the impact of these decisions. For this purpose, incidents from literary texts may also be used.

Team Work: Positive collaboration in the form of team work is critical in the classroom environment, for which it is necessary to transcend one's prejudices and predilections so as to achieve the desired outcomes. In the process of team work, leaners will acquire the skills of managing knowledge acquisition and other collaborative learners, thereby understanding how to incorporate and balance personalities.

Study Visits: Study Visits provide an opportunity to students to test their in-class learning in real life situations as well as to understand the functional diversity in the learning spaces.

These may include visits to sites of knowledge creation, preservation, dissemination and application. Institutions may devise their own methods to substitute/modify this aspect.

1.7 ASSESSMENT METHODS:

Alignment of Programme Learning Outcomes and Course Learning Outcomes: The assessment of learners' achievement in BA/B Sc/ B Com English (CBCS) will be aligned with the following:

- programme learning outcomes (graduate descriptors)
- course learning outcomes (qualification descriptors)
- academic and professional skills suggested in the graduate learning descriptors in the LOCF recommendations (indicated and illustrated in the Learning Outcomes in respect of select courses)

Assessment priorities: Institutions will be required to prioritize formative assessments (in-semester activities including tests done at the department or instructor level) rather than giving heavy and final weightage to summative assessments (end-semester and/or mid-semester tests traditionally done centrally). Progress of learners towards achieving learning outcomes may be assessed making creative use of the following, either independently or in combination:

- Time-constrained examinations (say 1-hour or 2-hour tests)
- Closed-book and open-book tests (if applicable, rather than doing as a rule);
- Problem based assignments
- Real life simulations
- Observation of practical skills (speaking, listening, problem solving within a peer group or a class)
- Individual project reports (case-study or term papers within a given word limit)
- Team project reports
- Oral presentations, including seminar presentation
- Viva voce, interviews
- Computerised adaptive testing for MCQ
- Peer and self-assessment etc. and any other pedagogic approaches as may be relevant keeping in view the learners' level, credit load and class size.

Diversity in Assessment Methods: Allowing for the diversity in learning and pedagogical methods adopted by different universities and institutions, stakeholders (Academic Councils, Boards of Studies or statutory bodies) are expected to ensure that the objectives of the course(s) are clearly aligned to learning outcomes. It is expected that the curricula developed by institutions will maintain a transparent roadmap of (a) pedagogical methods and priorities and (b) learning outcomes that reflect the weightage points given to different aspects of skills and achievements identified in the recommendations.

Learning Outcomes Index: While devising assessment modes and criteria, institutions may look to gridlock course learning outcomes and programme learning outcomes as indicated in the LOCF BA/B Sc/ B Com English (CBCS), and work out ways to assign credit loads and distribute weightage points for each.

Innovation and Flexibility: Within each category, institutions are expected to encourage instructors to bring in innovative and flexible methods to guarantee the fullest realization of Learning Outcomes outlined in the document. All such instructional and assessment requirements must be clearly communicated to all stakeholders at the time of course registration. Any subsequent change or minor modification necessary for fuller realization of learning outcomes must be arranged with due notice and institutional arrangement at the relevant level.

Freedom and Accountability: Freedom and accountability of the stakeholder are key attributes that determine the success of the Learning Outcomes Framework. For example, in research work, learners may be asked to pay attention to library work and survey of literature, originality of ideas, formulation of arguments, and creativity. Components may be assigned weightage points accordingly (say, x:y:z for different components out of 15 points). The excellence of institutions will be increasingly determined by Learning Outcomes rather than programme or course objectives. Hence it is necessary to innovate continually in learning and assessment in order to ensure meaningful and socially relevant learning (with transparent Learning Outcomes indices) rather than rote learning.

Clustering of Activities: Each cluster of activity may be assigned weightage points in accordance with the priorities of the institution without diluting the principles given in the LOCF. So an institution may choose to have any or all of the following in its in-semester activities with clear and transparent methods of communication to learners: open viva voce, group quiz or individual, classroom simulations and problem solving activities, library or field visits, term papers, individual and group reports, poster presentations. Credit hour and L-T-O distribution shall be crucial to any such clustering.

Review and Amendment: It is important for institutions to review, periodically and without fail, the efficacy of any method adopted to meet the learning outcomes proposed in the LOCF recommendations. Institutions are also required to make statutory provisions to adapt/modify/amend rules and clauses as may be necessary without violating the spirit of the larger programme outcomes outlined by the UGC in the CBCS guidelines.

Spirit Rather than Letter of the LOCF: The guidelines for assessment given here and elsewhere in the LOCF recommendations are indicative rather than exhaustive. So institutions are expected to frame assessment modes and criteria relevant to their situation and context, in keeping with the spirit of the LOCF. The basic idea of LOCF (B A/B Sc/B Com English [CBCS])—that learners at this level should understand their position(s) in the light of regional, national and global perspectives—must find a true and transparent reflection in the assessment.

Appendix 1:

1.8 Structure of B A/B Com/B Sc under CBCS English

[Note: These courses are meant for undergraduate education in arts, science and commerce, to be offered to students as skill enhancement courses. The number of electives in addition to the two core courses shall be decided by the Departments/BoS/AC keeping in mind the total credit load and overall credit requirements for course across the board.]

Core Courses

1. AEEC/SEC 1: Basic English Communication Skills

a. Grammar
b. Listening and Speaking
c. Basics of Reading
d. Basics of Writing

2. SEC 2: Advanced English Communication Skills

a. Advanced Reading
b. Advanced Writing
c. Principles of communication and communicative competence
d. Cross Cultural Communication

SE Electives

1. Creativity Through Language
2. Dictionary and Reference Skills
3. Appreciating Literature

1. SEC Course 1: Basic English Communication Skills

Course Statement

The aim of this course is to help students become familiar with nuances of grammar, and build confidence in them that grammar is 'learnable'. The course also helps the learners become aware of language, its dependence on grammar and the variety it exhibits. This course will be offered under four headings as given below:

a. Grammar
b. Listening and Speaking
c. Basics of Reading
d. Basics of Writing

Course Level Learning Outcomes

Some of the course learning outcomes that learners of this course are required to demonstrate runs thus:

- Identify deviant use of English both in written and spoken forms
- Recognize the errors of usage and correct them
- Recognize their own ability to improve their own competence in using the language
- Understand and appreciate English spoken by people from different regions
- Use language for speaking with confidence in an intelligible and acceptable manner
- Understand the importance of reading for life
- Develop an interest for reading
- Read independently unfamiliar texts with comprehension
- Understand the importance of writing in academic life
- Write simple sentences without committing errors of spelling and grammar

Course Content

i. Major basic grammatical categories
ii. Notion of correctness and attitude to error correction
iii. Importance of listening skills
iv. Problems of listening to unfamiliar dialects
v. Aspects of pronunciation and fluency in speaking
vi. Intelligibility in speaking
vii. Introduction to reading skills
viii. Introducing different types of texts – narrative, descriptive, extrapolative

ix. Introduction to writing skills
x. Aspects of cohesion and coherence
xi. Expanding a given sentence without affecting the structure
xii. Reorganizing jumbled sentences into a coherent paragraph
xiii. Drafting different types of letters (personal notes, notices, complaints, appreciation, conveying sympathies etc.)

Suggested Reading

1. Acevedo and Gower M (1999) *Reading and Writing Skills.* London, Longman
2. Deuter, M et.al. (2015). *Oxford Advanced Learner's Dictionary of English (Ninth Edition).* New Delhi, OUP
3. Eastwood, John (2008). *Oxford Practice Grammar.* Oxford, OUP
4. Hadefield, Chris and J Hadefield (2008). *Reading Games.* London, Longman
5. Hedge, T (2005). *Writing.* Oxford, OUP
6. Jolly, David (1984). *Writing Tasks: Stuidents' Book.* Cambridge, CUP
7. Klippel and Swan (1984). *Keep Talking.* Oxford, OUP
8. Saraswati, V (2005). *Organized Writing 1.* Hyderabad, Orient Blackswan
9. Swan, Michael. (1980). *Practical English Usage.* Oxford, OUP
10. Walter and Swan (1997). *How English Works.* Oxford, OUP

2. SEC COURSE 2: ADVANCED ENGLISH COMMUNICATION SKILLS

Course Statement

The course has a focus on helping learners develop their skills of Reading, Writing and communication skills. It builds their competence further in Reading and Writing to facilitate their academic pursuits. Further, it also builds their ability to communicate effectively with a wider range of people especially for professional purposes. The learner is made aware of all aspects of effective communication and skills required for acquiring as well as conveying information. The course will be offered under four headings as given below:

a. Advanced Reading
b. Advanced Writing
c. Principles of communication and communicative competence
d. Cross Cultural Communication

Course Level Learning Outcomes

Some of the course learning outcomes that learners of this course are required to demonstrate runs thus:

- Read and understand longer pieces of discourse independently
- Read and compare two texts for evaluating them
- Summarise a text for the benefit of peers orally or in writing
- Read and re-narrate a piece of text either orally or in writing
- Plan a piece of writing before drafting – brainstorming and developing web-charts/flow-diagrams/outlines
- Edit a piece of self and peer writing
- Writing and revising the drafts
- Write a review of a text read for academic purpose or pleasure
- Understand the purpose and process of communication
- Identify and overcome barriers of communication
- Understand and appreciate the social norms of communication
- Understand and appreciate the principle of politeness in relation to the speaker/listener

Course Content

i. Reading texts of different genres and of varying length
ii. Different strategies of comprehension
iii. Reading and interpreting non-linguistic texts
iv. Reading and understanding incomplete texts (Cloze of varying lengths and gaps; distorted texts.)
v. Analysing a topic for an essay or a report
vi. Editing the drafts arrived at and preparing the final draft
vii. Re-draft a piece of text with a different perspective (Manipulation exercise)
viii. Summarise a piece of prose or poetry
ix. Using phrases, idioms and punctuation appropriately
x. Introduction to communication – principles and process
xi. Types of communication – verbal and non-verbal
xii. Identifying and overcoming problems of communication
xiii. Communicative competence
xiv. Cross-cultural communication

Suggested Readings

1) Bailey, Stephen (2003). *Academic Writing.* London and New York, Routledge.
2) Department of English, Delhi University (2006). *Fluency in English Part II.* New Delhi, OUP
3) Grellet, F (1981). *Developing Reading Skills: A Practical Guide to Reading Skills.* New York, CUP
4) Hedge, T. (2005). *Writing.* London, OUP
5) Kumar, S and Pushp Lata (2015). *Communication Skills.* New Delhi, OUP
6) Lazar, G. (2010). *Literature and Language Teaching.* Cambridge, CUP
7) Nuttall, C (1996). *Teaching Reading Skills in a Foreign Language.* London, Macmillan
8) Raman, Meenakshi and Sangeeta Sharma (2011). *Technical Communication: Principles and Practice.* New Delhi, OUP

1.9 SEC/ ELECTIVES:

SEC (ELECTIVE): CREATIVITY THROUGH LANGUAGE

Course Statement

The aim of this course is to help learners identify, appreciate as well as use language in multiple creative ways. Learners will be sensitized to the creative process and learn to craft language aesthetically. They will be exposed to the various areas where language can be used creatively be it the conventional literary modes such as poetry, short story and drama as well as advertisements, songs and newspaper reports. Learners will also develop an awareness of the process of translating a text and the cultural contexts of language. Finally, learners will develop a critical engagement with texts in the process of reviewing films and books.

Course Level Learning Outcomes

Some of the course learning outcomes that learners of this course are required to demonstrate runs thus:

- Demonstrate the ability for creative thinking and critical analysis of literature and media
- Show how figures of speech and idioms work in the understanding of texts
- Demonstrate how a text interacts with the creative reader in the process of interpretation
- Show their useful creative skill in writing , drafting and reading
- Review literary and non-literary texts
- Understand the importance of social media in the present context
- Assess their own creative competence
- Respond with sensitivity to the gender and cultural nuances in which a text is located (Value addition)

Course Content

1) Art and Craft of Language
    - Figures of speech, idioms, phrases, proverbs
    - Dialects, registers, codes
    - Gender and language
    - Physical disability and language

2) Appreciating Creativity I
    - Poetry
    - Dramatic Dialogue
    - Short Story
    - Translated short stories, editorials, poems, songs, advertisements
3) Appreciating Creativity II
    - Advertisement and its types
    - Newspaper reports
    - Painting and Film reviews
    - Cyber media and social media

Suggested Reading

1. Baker, Mona (2011). *In Other Words: A Coursebook on Translation.* London, Routledge.
2. Bassnett, Susan. (2002). *Translation Studies.* London, Routledge
3. Dev, Anjana N et.al. (2008). *Creative Writing: : A Beginners Manual.* Delhi, Pearson
4. Fiske, John (1982). *Introduction to Communication Studies.* London, Routledge.

2. SEC (ELECTIVE): DICTIONARY AND STUDY SKILLS

Course Statement

This paper provides to the students a perspective on usefulness of Dictionaries in language learning and also highlights the importance of reference skills in academic pursuits. The course that is offered in two parts will first focus on using dictionary for different purposes. It begins with tasks on familiarizing the learners with the structure of a dictionary and gradually takes them to various aspects of its use. The second part deals with reference or study skills which emphasises the need to become independent learners. The course helps the learners realise that accessing knowledge is better than receiving it from a secondary source.

Course Level Learning Outcomes

Some of the course learning outcomes that learners of this course are required to demonstrate runs thus:

- Demonstrate their ability to use a dictionary easily
- Understand the multiple uses of a dictionary
- Identify different parts of a dictionary and their uses
- Use different types of dictionary for different purposes
- Appreciate the need for reference/study skills
- Make/take notes systematically in an organized manner
- Develop graphs, charts, grids and other visual support to understand a text
- Use catalogues, indices and other reference materials in library or at home
- Cite books referred to in a systematic and acceptable manner

Course Content

i. Introduction to a dictionary and its types
ii. Mapping a dictionary to locate words easily
iii. Multiple uses of dictionary/ies
iv. Introduction to Thesaurus/Lexicon/Activator/Encyclopedia and their uses
v. Importance of study skills in academic life
vi. Principles of Note making/taking
vii. Information transfer exercises
viii. Classification tasks and their importance in language learning
ix. Using library resources properly
x. Citing references or developing a bibliography

Suggested Reading

1. Cortell, Stella. (2008). *The Study Skills Handbook.* London, Palgrave Macmillan
2. Deuter, M et.al.(Ed) (2015). *Oxford Advanced Learner's Dictionary of English. (Ninth Edition).* New Delhi, OUP
3. Kahn, John E (Ed) (1990) *Illustrated Reverse Dictionary*. London, New York, The Reader's Digest Association Ltd.
4. Summers, Della (Ed) (2008). *Longman Essential Activator*. Harlow, Longman
5. Wallace, M J. (2004). *Study Skills in English.* Cambridge, CUP

3. SEC (ELECTIVE): APPRECIATING LITERATURE

Course Statement:

The focus of this course is to expose the students to varied nuances of literary texts in terms of genre. The skills needed for a valid interpretation of a literary text involves a close reading of the text accompanied by a clear understanding of form, contexts and linguistic devices. The aim is to sensitise the students to the fact that different literary texts need to be interpreted through specific sets of tools.

Course Level Learning Outcomes

At the end of the course, the learners will be able to:

- Show how imagery and figures of speech work in poetry and use the analysis of these to arrive at an interpretation of the poem.
- Identify rhyme, beats, sound pattern in a poem and analyse the rhythm of heroic couplets, blank verse and free verse.
- Demonstrate how a dramatic text interacts with a reader in the reading process for meaning and interpretation.
- Identify the performative aspects of a dramatic text
- Demonstrate the ability to identify various aspects of story telling in terms of plot, character, linguistic devices and form in a short story
- Demonstrate the ability for critical thinking and close reading of literary texts from the larger perspectives of culture, society, history and gender.
- Show their useful interpretative skill.

Course Contents

(i) **Poetry**:

Major categories of Poetry: lyric, narrative,
dramatic Verse form: rhymed verse, blank verse,
free verse Imagery, diction, syntax, Rhythm and its
functions
Interplay of sense, feeling, tone and intonation in poetic communication

(ii) **Drama**:

Major categories of Drama: comedy, tragedy, tragi-comedy

Elements of drama: Plot, character, language (dialogue and soliloquy), setting (stage directions and props)

(iii) **Short Story**:

Types of short stories

Aspects of story telling

(iv) **Contexts of Literature**: author, reader, intertextuality, history, society, culture, gender

Suggested Reading

1. Baldick, Chris (2008) *Oxford Dictionary of Literary Terms*, OUP.
2. Cuddon, J.A. (2014) *Penguin Dictionary of Literary Terms and Literary Theory*, Penguin Books.
3. Green, David (1974) *The Winged Word: An Anthology of Poems for Degree Course,* Macmillan.
4. Scholes, Robert E (1991) Elements of Literature(Section on short story in particular), OUP
5. Styan, J.L(1965) The Dramatic Experience: A Guide to the Reading of Plays, CUP
6. Wainwright, Jeffrey (2004) *Poetry: The Basics*, Taylor & Francis

1.10 Appendix 2: BA Litt (Non-Hons)

English Literature for Generic Elective (GE) for students majoring in subjects other than English and Discipline Specific Core (DSC) for students pursuing BA without any major (Honors) subject

COURSE 1 (DSC/ GE): INTRODUCTION TO LITERATURE

Course Level Learning Outcomes

Some of the learning outcomes of the course ‘Introduction to Literature’ that learners of the course are required to demonstrate run thus:

- Understanding of issues like literature, literariness, literary values and basic literary concepts
- have a basic understanding of development of English literature in terms of various movements
- engage with the genres and forms of English literature and develop fundamental skills required for close reading and critical thinking of the texts and concepts
- appreciate and analyse the select literary poems and plays in the larger socio-cultural contexts of the time
- develop skills of critical analysis and interpretation of selected poems in order to understand the theme, language, tone and style, and elements of prosody

Course content

Unit A: Essay or excerpts on Reading Literature on topics like ‘why read literature’, ‘the meaning of literature’, ‘literariness’, literary values’, ‘function of literature’, pleasure of reading, introduction to major literary concepts

Unit B: Brief Outline of English literature and its main Movements (Classicism, Romanticism, Realism, Naturalism, Expressionism, Symbolism and Modernism)

Unit C: Tales and stories (selections from different traditions of storytelling such as *Panchatantra*, Aesop’s Fables, selections from *Tales from Shakespeare*, S Maugham and any others)

Unit D: Epic (excerpts from The *Mahabharata*, *Illiad*, *Odyssey*, or *Paradise Lost*) or Drama (Shakespeare/Shaw/Checkov)

Unit E: Novel (Bach: *Jonathan Livingstone Seagull*) or collection of short stories

Unit F: Nonfiction: Essays (examples) or Autobiography/Biography/Travel Writing

NB: The texts mentioned here are indicative. Universities, Board of Studies can choose a text or a excerpts with justification.

Suggested Topics:

- Individual and Society
- Relationship between Religious, philosophical and political thought
- Themes of war, love, death, and homelessness
- Literature, culture and society
- Literature and other forms of art/media (Inter-mediality)
- Literature and films

Suggested Activities:

Workshops on Appreciating literature, poetry, drama, short stories, novels and comparison between literary works and their filmed or adapted versions

Suggested Readings

W H Hudson, *An Introduction to the Study of English Literature*, Maple Press, 2003 ed.

P. Varghese, *Introduction to English Literature*, Alfa Publications, 2011.

Martin Gray, *A Dictionary of Literary Terms*, Blackwell, 1998.

Terry Eagleton, *How to Read a Poem,* John Wiley & Sons, 2011 ed.

Stephen Greenblatt, et al. eds. *The Norton Anthology of English Literature,* Norton & Co. 2012 ed.

2. COURSE 2 (DSC/ GE): BRITISH LITERATURE

Course Level Learning Outcomes

Some of the learning outcomes that students of this course are required to demonstrate run thus:

- understand English literary cultures from the Renaissance to the present
- develop an understanding of different forms and types of British Literature through exposure to texts that highlight both compliance and contest to tradition
- appreciate and analyze the texts in the larger socio-political and religious contexts of the time
- demonstrate an awareness of nuances of the English language and its varieties
- extend the knowledge of life in literature (say of animals, environment, gender, politics, nationalities, personal and ideological differences) to life and living situations

Suggested Course Content.

Stakeholders may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

Poetry

1. William Shakespeare (a sonnet or a short poem), or John Donne "The Sun Rising" or "A Valediction Forbidding Mourning" or John Milton, "On His Blindness"
2. William Wordsworth, "The Solitary Reaper" or John Keats "La Belle Dame sans Merci" or Christina Rossetti, "After Death"
3. W B Yeats, "Sailing to Byzantium" or T S Eliot, "To the Indians who Died in Africa" or A Love Song of J Alfred Prufrock", or Seamus Heaney, "Digging" or "Blackberry-Picking"

Drama

G B Shaw: *Arms and the Man* or J M Synge: *Riders to the City*

Fiction (any one text)

Virginia Woolf, *To the Lighthouse* or George Orwell, *Animal Farm*
or Kazuo Ishiguro, *The Remains of the Day* or Hanif Kureishi: *The Buddha of Suburbia*

Or

Three stories, preferably from different periods (Charles Dickens, "A Christmas Tree" or Wilde, "The Selfish Giant" or Rudyard Kipling, "The Miracle of Purun Bhagat" or "Lispeth")

Non-Fictional Prose and Essays

Essays from different periods (at least three Orwell, "Shooting an Elephant" or Virginia Woolf, "Shakespeare's sister" or Terry Eagleton, "The Slow Death of the University") or short autobiographical texts (Excerpts from Frank Kermode, *Not Entitled, A Memoir* or travelogues (Excerpts from Mark Shand: *River Dog*)

Suggested Topics

- Forms of English Popular Culture
- The English Countryside
- The Rise of Colonialism
- Different Forms of Storytelling
- Role-Playing in Life and Literature
- Literature and Social Conventions
- Environmental Consciousness in Literature

Suggested Readings

Peter Alexander, *A History of English Literature*, 3rd ed. Palgrave Macmillan, 2017.

M. H. Abrams, *A Glossary of Literary Terms*, 11th ed. Cengage, 2015. [Entries on drama, fiction, specific types of poetry]

Robert Scholes, et al, eds. *Elements of Literature*, rpt. OUP, New Delhi, 2010. [Sections on Poetry, Fiction, Essays and Drama].

3. COURSE 3 (DSC/ GE): MODERN INDIAN LITERATURE

Course Level Learning Outcomes

Some of the course learning outcomes that learners of this course, Modern Indian Literature, are required to demonstrate runs thus:

- Demonstrate the ability to read literary texts in terms of genre and contexts.
- engage with and write cogently on issues specific to modern India and to local realities
- critically appreciate the use of English in India

Suggested Course Content:

Poetry:

i. Kamala Das, "An Introduction"

ii. Nisssim Ezekiel, "Background, Casually"

iii Agha Shahid Ali, "The Dacca Gauzes"

iv. Arundhathi Subramaniam, " Where I Live"

v. Anamika, "Women"

vi. Temsula Ao, "The Old Story Teller"

Novel: Bama *Karukku*/Arup Kumar Datta, *Kaziranga Trails*

Short Fiction

Shashi Deshpande, "The Inner Rooms"

R.K. Narayan, "Engine Trouble" Ambai, "Squirrel"

Drama

Girish Karnad, *Tughlaq/*

Mahesh Dattani, *Final Solutions/*

Manjula Padmanabhun, *Lights Out*

Topics

- Role of English in India
- The construction and politics of Gender in India
- The role of community, religion and caste

- Representing conflict and resistance

Suggested Readings

BR Ambedkar, *Annihilation of Caste*

Kamla Bhasin, *Understanding Gender*, Kali for Women, 2000

Amit Chaudhuri, Introduction to *The Picador Book of Modern Indian Literature*, 2001

Meenakshi Mukherjee, "Divided by a Common Language", in *The Perishable Empire*, New Delhi: OUP, 2000. pp. 187--203

4. COURSE 4 (DSC/ GE): NEW LITERATURES IN ENGLISH

Course Level Learning Outcomes

Some of the course learning outcomes that learners of this course, New Literatures in English, are required to demonstrate runs thus:

- show familiarity with the emergent body of literature being produced by writers from South Africa, Caribbean, South Asia, Australia and Canada and its socio-political- cultural contexts
- demonstrate ability to show an understanding of cultural exchange processes as represented through literature will have knowledge about the prominent concepts in this body of literature.
- appreciate new works in literature and pursue their interests in it
- examine different ways of reading and using literary texts across wide range of classical authors, genres and periods with comparative perspectives
- develop ability to pursue research in the field of new literatures in English

Course Contents

Novel

Amitav Ghosh, Shadow Lines Chimmanda
Ngozi Adichie, Half of a Yellow Sun

Margaret Atwood, *The Blind Assassin /*

Tahmima Anand, *A Golden Age /*

Margaret Atwood, *The Blind Assassin* /

Mohsin Hamid, *The Reluctant Fundamentalist*

Poetry

Derek Walcott, “A Far Cry from Africa”

Yasmine Gunaratne, “Big Match”

Oodgeroo Noonuccal, “The Dawn is At Hand” /

Gwen Harwood, “In the Park”

Short Fiction

Patrick White, “The Age of a Wart”

Sally Morgan, “Daisy Corunna’s

Story”

Ngugi Wa Thiango, “The Upright Revolution: or Why Human Walk Upright”

Nadine Gordimer, “Six Feet of the Country”

Suggested Readings

Ulka Anjaria, ed. *A History of the Indian Novel in English*, Cambridge UP, 2015.

Elleke Boehmer and Rosinka Chaudhuri, eds. *The Indian Postcolonial: A Critical Reader*, London; New York: Routledge, 2011

Neil Lazarus *Resistance in Postcolonial African Fiction*, New Haven: Yale University Press, 1990.

Sheila Collingwood-Whittick, ed. *The Pain of Unbelonging*: *Alienation and Identity in Australian Literature*, Amsterdam & New York: Rodopi, 2007.

Robert D Hammer, *Critical Perspectives on Derek Walcott*. Colorado: Lynne Reinner Publishers, 1997.

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LEARNING OUTCOMES BASED CURRICULUM FRAMEWORK (LOCF)

For

UNDER-GRADUATE PROGRAMMES

In

VISUAL ARTS
&
PERFORMING ARTS

ज्ञान-विज्ञान विमुक्तये
UGC
University Grants Commission

Bahadur Shah Zafar Marg
New Delhi-110 002

2020

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.

DPSingh

New Delhi
30th July, 2019

(Prof. D. P. Singh)
Chairman
University Grants Commission

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PREAMBLE:

i. The learning outcomes are formulated to help students understand the objectives of the visual and performing arts courses at the undergraduate level and to get them acquainted with contemporary artistic and social needs. Students will be enabled to understand the philosophy behind their art and master the grammar and techniques of their chosen art form, develop artistic skills that would enhance their expression and communication abilities.

ii. Students will also be encouraged to explore and express their ideas and concepts, as well as to learn to use their art form creatively and critically; to learn to develop their understanding of the gained knowledge and to search for ways to express their thoughts and feelings through their medium of art.

iii. While selecting and designing materials for the syllabus, the faculty in Departments/Universities/Institutions may decide to vary their course content, with justifications. Objectives and organizing principles should be finalized keeping in view the local, regional, national, and global contexts of creation, appreciation, and evaluation.

iv. This LOCF document is not prescriptive, but indicative. It does not prevent further rethinking or inclusion of specific elements in their courses, to suit the local context.

v. The organization of the course may be structured to suit the institution's academic framework (annual, trimester, semester, etc.).

vi. Suitable modules could incorporate residencies, internships, interaction with gurus, etc, and appropriate credits awarded for the same.

vii. Further, teaching-learning processes may be suitably adapted, incorporating the similarities and diversities of culture and art practices.

viii. The Department/University/Institute may encourage its facultyto make suitable pedagogical innovations, in addition to teaching/learning processes suggested in the LOCF recommendations.

ix. The committee noted a diversity of nomenclatures in the Visual Arts fields in different Department/University/Institution and suggests the need for uniform nomenclature to avoid confusion in admissions/appointments. For example, an undergraduate program in

Fine Arts could be called: Bachelor of Fine Arts (with specialization in Painting, Sculpture, Applied Arts, etc)

x. The courses designed could go beyond the primary field of study and expose students to domains such as literature, cinema, and the digital arts.

xi. Students may be encouraged to work on various art forms that are on the verge of extinction, besides the living traditions, as part of their learning process. The students may be encouraged to study such art forms from experts/ gurus who may not necessarily be from a formal institutional setup.

xii. Visual and Performing Arts programs should be formulated with more stress on practice.

xiii. Visits to museums, places of historical importance, art studios/ galleries, theatre spaces, and other appropriate locations must be made part of the curriculum. Such an arrangement will help students discover and familiarise themselves with both classical and contemporary art forms.

xiv. The role of digital arts and evolving multi-media methods must be emphasized and applied where appropriate.

xv. The Visual Arts curriculum, in particular, may be framed in such a way that it provides adequate exposure to the fine arts (painting & printmaking, sculpture) as well as the applied arts (advertising, animation, textile & fashion design, interior design, art management, etc.) with appropriate specialization where required.

The LOCF for Visual and Performing Arts is prepared on the contours and curricular framework provided by the UGC and may be modified without sacrificing the spirit of CBCS and LOCF. The courses can be prepared by the respective institutions keeping in mind the above points.

1. INTRODUCTION

The experience of art is a way of enriching the quality of human experience. It requires an intensity of interest in the creative faculties of human life, as well as an awareness of the surrounding social milieu. Any creative person and practicing artist needs knowledge of past/historical achievements, awareness of present/contemporary challenges, and an inkling of future/unseen possibilities in the realm of art; as well as refinement of taste, building up criteria, and decision about values. It is essential to put in hard work, rigorous practice, and lots of reading/listening/seeing. A dedicatedly professional approach is needed to pursue the arts. The artist of the next generation shall be a product of university education rather than of the self-taught kind; although the Ekalavya spirit has to be nurtured too, as over-institutionalized education can be stifling.

The Learning Outcomes-based Curriculum Framework (LOCF) for BFA (Painting, Applied Arts, and Sculpture, etc) and BPA (Music, Dance, and Theatre) 4-year degree programs are designed to make the education of the arts more specific and systematic and on par with professional courses, as well as to revitalize existing courses in various institutions and open up areas of non-developed possibilities.

2. LEARNING OUTCOMES BASED APPROACH TO CURRICULUM PLANNING

The basic premise of the LOCF approach to curriculum is that students earn their degree based on:

a) Demonstrated achievements of the outcomes (knowledge, understanding, skills, attitudes, and values) and,
b) The academic standards are expected of a program of study.

The expected learning outcomes outlined in this document would help faculty members formulate their course syllabus based on qualification descriptors, program learning outcomes, and course learning outcomes. Revisiting this document periodically would help the faculty members review and revise their syllabus to make teaching-learning more effective while empowering the learner to face the challenges once s/he graduates.

This document outlines:

a) What the learners are expected to comprehend in the said art form
b) Be able to do at the end of their course

This document, while providing some basic essential guidelines on setting up a course curriculum and syllabus also provides for flexibility and innovation for a faculty member in terms of course delivery.

The graduate attributes for Visual Arts and Performing Arts are indicative and guide faculty members in formulating their course syllabus, reflect on the teaching-learning process, spell out learning outcomes, create and implement assessment modes that will help them deliver an effective course. Needless to say, the learning outcomes should always reflect the changes in the field of study.

This document focuses on *what is to be taught* and *what is learned* by providing demonstrable outcomes. The idea is to integrate social needs and pedagogical practices in a manner that is responsive to the evolving needs of the field of study.

3. GRADUATES ATTRIBUTES IN THE SUBJECT

The Graduate Attributes (GAs) reflect particular qualities and abilities of an individual learner including gaining knowledge, application of obtained knowledge, professional and life skills, acquiring attitudes and human values that are necessary for Visual and Performing Arts graduates at the Higher Education Institutions (HEIs). The graduate attributes include capabilities to strengthen one's professional abilities for widening current knowledge and employability/self-employability skills, undertaking future studies for local and global application, performing creatively and professionally in a chosen career, and ultimately playing a constructive role as a socially responsible human being.

Any graduate of Visual and Performing Arts graduate should be a learning thinker with an understanding of the core concepts in the arts and a responsibility towards society.

Graduate Attributes include:

- **Continuous Learning**: To engage in self-reflection and lifelong-learning through the arts, while keeping social awareness intact.
- **Artistic skills**: To acquire all the necessary skills needed to make one’s performance and practice credible.

- **Experimentation:** a) To experiment with the medium, form, structure, colour, tone and texture, methods, and materials of the particular visual and performing art. b) To enhance aesthetic sensibility in everyday life.
- **Interpretative Skills**: To study and analyze the textual and performing traditions and practices as well as to critically and creatively interpret and enhance appreciation of beauty and utility.
- **Social Awareness**: To be aware of the diversity, complexity, and contestations of the past and present socio-culture milieu of the country during the process of art-making.
- **Social Responsibility**: To build up the capacity to take up social and civic responsibilities relating to the environment and society.
- **Communication Skills**: To inculcate transferable skills including team building & leadership skills, creative & critical skills, and problem-solving skills suitable for a variety of fields of employment/self-employment.
- **Introspection**: To constantly introspect and assess oneself in the never-ending artistic journey.

4. QUALIFICATION DESCRIPTORS

<u>Students must be able to:</u>

- ❖ Demonstrate a coherent and systematic knowledge and understanding of the developments in theory and practice in the Visual and Performing Arts.
- ❖ Identify, analyze, interpret, compare, evaluate, speak and write about the content and form of genres, artistic *isms* (Eg: realism, surrealism), schools (Eg: *gharanas,pahari* school, etc), periods, movements as well as to perform in various modes and styles, exploring a range of subjects and expressing in a variety of forms.
- ❖ Understand the role of Visual and Performing Arts in a changing world from the disciplinary perspective, as well as with its professional and everyday use.
- ❖ Think and perform clearly about one's role as a practitioner through a critical understanding of the texts, visual, and performing traditions.
- ❖ Communicate ideas, opinions, and values—both art and life.
- ❖ Recognize and explore the scope of the Visual and Performing Arts in terms of career opportunities, employment/self-employment, and lifelong engagement.

5. PROGRAMME LEARNING OUTCOMES

Visual Arts:

After completing the undergraduate program, a learner of **Visual Arts** (any stream) should be able to:

- Demonstrate a comprehensive understanding of the history of art and aesthetics theoretically
- Understand the nature of time, space, colour, form, tone and texture
- Critically evaluate masters as well as contemporary artists
- Create their own works of art using a range of methods and materials
- Execute art projects independently
- Participate in solo/group shows
- Teach fine arts to school students
- Become an applied arts entrepreneur

Performing Arts (Music):

After completing the undergraduate program, a learner of ***Performing Arts*** *(Music) should* be able to:

- Demonstrate a fair understanding of:
  - a) The nuances of Indian melody-based classical music
  - *b) Shruti-shastra*and *laya-tatva*
  - c) *Bandish/ kriti*in a*raag* and perform the same
  - d) *Taal* and perform the same
  - e) Languages and dialects of musical compositions
  - f) Music notations
  - *g)* Characteristics of various *Gharnas*
  - h) Salient features of the art form-folk, devotional, film/Natya- and popular music
- Render compositions in the least ten of raags and five number of taals
- Demonstrate a critical understanding of the style of old masters
- Improvise during performance
- Participate in concerts

Performing Arts (Dance):

A student should have a fair understanding/proficiency of:

- *Taal*, *laya* aspect with precision and clarity.
- Movements (*kshep*), gestures (*hastakas*), symbols (*mudras*), stances/poses with stylization-specific grace.
- Expressional aspect (*bhava/abhinaya*) with emotive ability and sensitivity.
- Accompanying music and musical instruments of one's own style.
- The mythological, philosophical, and literary content of the dance compositions.
- Attributes of different *gharanas* regarding *hastak*, *ang*, music/rhythm, *bandish*.
- Notation of rhythmic *bandish*.
- Costume and make-up in terms of traditional design, modifications regarding fabric texture, color, styles of the theme.
- Reasonable knowledge of sound and light systems used in a performance.
- Reasonable knowledge of recording techniques of a dance sequence.

After completing the undergraduate program, a learner of **Performing Arts** (Dance) should be able to:

- ❖ Demonstrate proficiency in the chosen style.
- ❖ Perform at least 30 minutes with good stamina, energy, and fluency.
- ❖ Analyze and logically explain the aesthetic and performing principles of the acquired knowledge.
- ❖ Teach the technique and presentation to students in schools.
- ❖ Create new pieces (rhythmic, thematic) and also modify already learned pieces with changing contexts, times zones, and locales.
- ❖ Appreciate other dance styles.
- ❖ Design and deliver a dance course for school students.

Performing Arts (Theatre):

After completing the undergraduate program, a learner of **Performing Arts** (Theatre) should be able to:

- Demonstrate a comprehensive understanding of:
  a) The basic elements of theatre (script, décor, lights, costume, makeup, background music acting, and direction).
  b) the nature of theatre as different from that of literature, visual arts, cinema, and other performing arts
  c) the composite, group and performing characteristics of the art form
  d) Principles of design
- Display basic knowledge of Indian and World classical, folk, and contemporary theatre histories.
- Demonstrate a set of basic skills in theatre appreciation, analysis, expression, communication, and explication.
- Demonstrate control over voice & speech and body & movements required for theatre
- Appreciate and analyze various theatre genres and styles.
- Employ reflexive thinking to analyze and interpret scripts and performances.
- Conceptualize, visualize and present theatrical performances.
- Uphold theatrical as well as socio-political values in practice.
- Recognize employment and self-employment opportunities in various theatre-related professions such as acting, writing, design, production, and management.
- Use digital media and other technologies in a theatrical experience, if need be.

6. TEACHING-LEARNING PROCESS

Learning can be made a challenging, engaging, and enjoyable activity. Learners should be encouraged to engage in a rigorous process of learning and self-discovery while focusing on key areas of the discipline and spending required time on practice. Experimentation and emphasis on the process would make learning meaningful.

To achieve its objective of process-based learning, focused work, and holistic development, the Department/ University/Institution can use a variety of knowledge delivery methods. Use of Open Education Resources (OERs) would help students get exposure to a wider range of practices across the world:

Methodology for Visual Arts:

- Lectures
- Lecture-Demonstrations
- Guided Visualizing & Seeing Sessions
- Understanding New Material and Methods
- Analyses of Exhibitions
- Workshops – intensive & extensive
- Residencies with gurus
- Study tours and Market Research
- Continuous Sketching & Drawings
- Tutorials - Assignments – Projects – Dissertations-Portfolio submissions
- Presentations: Classroom Creations & Public Exhibitions
- Studu of History of Art and Folk/ Traditional Art and Art Forms

Methodology for Performing Arts (Theatre) :

- Lectures
- Lecture-Demonstrations
- Guided listening and seeing sessions
- Guided reading modules—texts
- Analyses of play scripts and performances
- Workshops—intensive and extensive
- Everyday practice

- Rehearsals for performances
- Study tours
- Presentations: Classroom productions and public performances
- Voice and body exercises, improvisations and theatre games
- Tutorials - Assignments – Projects – Dissertations
- Guided, semi-guided and independent work—in stages

Methodology for Performing Arts (Music):

- Lectures
- Lecture-Demonstrations
- Guided listening sessions
- Shruti, raaga, taal analysis sessions
- *Riyaaz:* Everyday practice
- Improvisations
- Residencies with gurus
- Intensive workshops on language and dialects of compositions
- Tutorials - Assignments – Projects – Dissertations
- Classroom performances
- Public concerts

Methodology for Performing Arts (Dance):

- Lectures & Lecture-Demonstrations - of poets, painters, architects and designers, musicians, dancers of all styles, dance scholars, theatre personalities, etc.
- Guided sessions –viewing works of renowned dancers/choreographers/Gurus with the idea of explaining their contribution to the evolvement of dance
- *Riyaaz:* Everyday practice – under the supervision of an experienced dancer/teacher
- Improvisation: technique, stylization, depth, and nuances of *bha*va, presentation. A student should be guided to the process and then the aesthetic execution of improvisation.
- Study tours – to dance/theatre festivals, heritage sites, and museums.
- Residencies with gurus – (1) advanced training (possibilities and exploration of chosen style) (2) create awareness of other dance styles (3) to compare the

strengths/limitations of one's chosen style with other dance styles (4) knowledge of creating dance-specific music.

- Intensive workshops on language and dialects of compositions
- Tutorials - Assignments – Projects – Dissertations
- Classroom performances
- Public performances
- To collaborate with other art media like theatre, poetry, painting, sculpture since dance is a composite art form

7. ASSESSMENT METHODS

While creating assessment methods, faculty members may keep in mind:

- Program Learning Outcomes (PLO)
- Course Learning Outcomes (CLO)

Alignment to Learning Outcomes: Every assessment method created for a course may be aligned with the overall objectives of the academic program while meeting the specific learning outcomes requirements of the particular course. Emphasis may be laid on both academic and professional skills required as suggested in the graduate learning descriptors.

Evaluation Mode: The committee suggests a Continuous Evaluation Mode, with constant feedback, rather than a one-time summative evaluation mode at the end of the semester/ year. The weightage given to each assessment module may vary according to the learning outcomes suggested in this document.

Weightage: However, faculty members may take care to ensure that the assessment activities are accorded different weightage and spread throughout the semester/ year. For example, more weightage may be given for practical/ portfolio components.

Flexibility, innovation, and transparency: Faculty members are encouraged to come up with flexible and innovative ways of assessing the learners. However, care should be taken to ensure that the learner is aware of the mode of assessment, number of assignments, and the corresponding deadlines, right at the beginning of the semester/year.

On the whole, assessment methods may attempt a balance between both theoretical and practical inputs in the course, including life skills required for them to meet the challenges after they graduate. Assessment methods could include innovative use of materials and methods and help in identifying areas for employment, self-employment/ entrepreneurship.

Review: It would serve well for the University/ Department/ Institution to periodically review the syllabus, methods, and approaches to teaching-learning, and assessments to check if they are aligned with the learning outcomes. Suitable amendments may be made as per the institution's procedures after the review process.

8. KEYWORDS

Visual Arts, Performing Arts, gurus, theatre, music, dance, painting, sculpture, applied arts, fine arts, artistic skills, riyaaz, everyday practice, theory, performance, art shows, genres, entrepreneur, life-long learning, social values, attitudes, nature of time, space, colour, form, tone and texture, solo shows, shruti-shastra, laya-tatva, bandish, kriti, taal, masters, contemporary artist/es, script, décor, lights, costume, makeup, acting, direction, literature, visual arts, cinema, performing arts, Indian and World classical, folk, contemporary theatre, theatre appreciation, analysis, expression, communication, explication, theatre genres, styles, lectures, lecture-demonstration, projects, portfolio, study tours, residencies, workshops, exhibitions, continuous evaluation,

OBSERVATIONS:

Other Recommendation for Visual Art Courses:

i. The committee noted a diversity of nomenclature in the Visual Arts field in different universities/institutions and suggested certain uniform nomenclatures to avoid confusion in admissions/appointments both at the under-graduate and post-graduate program levels.
ii. Visual Arts programs should be formulated with more stress on practice.
iii. Visits to museums, places of historical importance, art studios/ galleries, and other appropriate locations must be made part of the curriculum. Such an arrangement will help students to develop a sense of discovery and familiarity with both classical and contemporary art forms.
iv. The curriculum should be framed in such a way that it provides exposure to fine arts (painting & printmaking, sculpture) AND applied arts (advertising and communication Design, design reproduction, animation, textile & fashion design, interior design, interaction design, industrial design, pottery and toy making, art management, etc.) with appropriate specialization where required.

Other Recommendation for Dance:

Indian classical dance and music represent the Indian ethos and psyche. The relevance and contemporary nature of classical dance and music do not warrant reiteration for the simple reason that they deal with the abstract and concrete aspect in full depth and vastness. Over time, the other art forms like painting, literature, theatre, have borrowed some aspects like technique, form, and content from the West. In that respect, Indian dance remains truly Indian, even today however advanced it may have become in terms of technical skill, possibilities of form, nuances of aesthetic sensibilities, and technological support. Classical dance today touches many contemporary issues, situations, and conflicts. However, classical dance, regrettably, is not represented internationally in good measure. Classical dance is one of our treasures and it needs better exposure on the international dance scene. In India, we have a wealth of classical dance (10 styles) and folk dances of various regions. On the contrary, the rest of the world together offers only classical ballet and modern dance.

It is strongly recommended that:

1) Students get exposure to the international dance scene by participating in international dance festivals.
2) Modules for workshops and dance appreciation courses be created for young graduates to effectively execute them, to create awareness amongst the dance fraternity abroad.
3) Collaboration between Indian dance and western dance be encouraged to create new aesthetics.

4) Platforms are created to enable closer interaction between established Indian dancers and our fresh graduates/post-graduates.

5) To create an atmosphere wherein advanced technical facilities can be used to make Indian classical dance more vibrant and dynamic to the present generation audience.

Enhanced exposure would lead to new ways of presentation, execution, treatment of thematic content. Our dance would get a different dimension if presented with the stage engineering available in the West. The richness and depth of our dance styles would grow if the aforesaid points are implemented.

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Learning Outcomes based Curriculum Framework (LOCF)

for

English Literature (B.A. Hons.)

Undergraduate Programme

2019

ज्ञान-विज्ञान विमुक्तये

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.

DPSingh

(Prof. D. P. Singh)
Chairman
University Grants Commission

New Delhi
30th July, 2019

Content

Preamble

The UGC Committee constituted for Learning Outcomes based Curriculum Framework for BA Literary Studies in English (Hons.) is pleased to submit its report.

The Committee suggests that the following global remarks may be taken into account by the faculty members, departments/schools, Boards of Studies in English, Institutes and Universities, while considering the recommendations for their use:

i. The learning outcomes are designed to help learners understand the objectives of studying BA (Honours) in English, that is, to analyze, appreciate, understand and critically engage with literary texts written in English, approaching them from various perspectives and with a clear understanding of locations.

ii. It is significant to mention here that the BA (Hons.) English syllabus under CBCS remains the point of reference for the LOCF recommendations. However, stakeholders (departments or universities or institutions) may make suitable alternations with justifications while selecting texts, finalizing objectives and organizing principles keeping in view global, national and regional contexts of analysis and appreciation.

iii. To this end, the texts mentioned in the LOCF document are indicative. Similarly, the organization of divisions / themes / genres / periods / authors / areas, etc. is specific to contexts identified in the course(s) and does not pre-empt further rethinking or selection with clear justification for the choices exercised therein.

iv. The organization of the courses/papers may be worked into semesters/years keeping in consideration the credit load in a given semester with the ultimate end of outcomes of the course/programme. However, it makes sense to include courses/papers that demand more attention in the second and third years (third to sixth semester as may be required) of the Honours course in English.

v. Learning outcomes are modifiable with due justification in view of contexts, texts selected in the course and requirements of the stakeholders, which are as diverse as are regions in the country

vi. The overarching concern of the LOCF committee in English is to have definite and justifiable course outcomes and their realization by the end of the course/programme.

vii. The Department/Institute/University is expected to encourage its faculty concerned to make suitable pedagogical innovations, in addition to teaching/learning processes suggested in the LOC Recommendations, so that the Course/Programme learning outcomes can be achieved.

BA Literary Studies in English (Hons)

Part I

1.1 Introduction

Outcome based learning is the principal end of pedagogical transactions in higher education in today's world in the light of exponential changes brought about in science and technology, and the prevalent utilitarian world view of the society. Since humanities is among the most questioned discipline, it is imperative to perspectivise literary studies in English at the UG and PG levels.

Humanities has ever been in crisis in the West, which has impacted social perception beyond the western shores including India, though the Indian mind, before the advent of colonization, related literature to '*kavya satya'* (poetic truth), which was different from other forms of truth, and hence not comparable to others. But humanities, poetry to be precise, has found its defendants in all ages.

The present crisis of humanities emanates from the predominance of science and technology in particular because it contributes to human conditions and comfort in tangible terms and thereby changing the human condition with material inventions. The resultant utilitarian society likes to invest in science and technology because it takes care of provisions for life. Literature, on the other hand, takes care of vision. But its impact is intangible and immeasurable in terms of quantity. Humanities or literary discourse brings about qualitative changes that remain immeasurable, but for its manifestation in human conduct that may be observed and experienced, but not quantified. However, what gets obviated in the process is that both of them *i.e*., science and technology and humanities-- are complementary, though those fascinated with tangible outcomes do tend to gloss over it. Fortunately, institutions of repute in management, also science and technology have started paying attention to humanities and social sciences, at least symbolically.

To speak of human values in an age in which humanities as a discipline itself is in a state of crisis may appear paradoxical.

The present century has increasingly realised the interconnectedness of all elements in the universe and interrelatedness of lives. Tim Cook speaks about maintaining balance between science and the humanities:

> If science is a search in the darkness, then the humanities are a candle that shows where we have been and the danger that lies ahead. It is technology married with liberal arts, married with the humanities that makes our hearts sing.

The function of literature is to bring the questions of values—human and literary—in focus.

Literariness is the ability of literature to attract attention to itself that it achieves through deviant use of language. As a system of knowledge, it aims at providing pleasure first and knowledge thereafter. Therein lies its value in being pleasant. Thereafter, the important thing is to know what literature is valued for. Literature is known for what it stands or its commitment. Literature celebrates life in all forms and stands for and with values of life by representing the weak, the poor, the exploited, the vulnerable and the voiceless. In a way, literary values are values of life, particularly human life.

Accordingly, English literary curricula have evolved over a period of time in India. From its Anglo-centric core, it moved to new literatures—Third World Literature, Commonwealth Literature, American, Canadian, Australian, African Literature, and New Literatures in English, and later to Indian Literature in English and Indian Literature in translation in the light of various critical and theoretical discourses like Post-modernism, Post-colonialism, Feminism, and Black Aesthetics/Dalit Aesthetics among others.

The present phase demands its alignment to the obtaining situation and demands. Its acceptance lies in its ability to enrich engagement with local and global realties, experiences and their manifestations in literary terms without glossing over the core attributes *i.e.*, human values. To achieve this, it is necessary for English studies to recognize and respect the differences and transcend binaries.

The question of relevance and acceptance of English literary studies follows. For local acceptance, it is necessary to have space for local literature and also contiguous literatures. For instance, for a Department of English located in Tamil Nadu may spare about 15 to 20 per cent space to literatures other than English like Tamil and Malayalam, Telugu or Kannada and to skill development.

The LOCF for English is prepared on the contours and curricular structure provided by the UGC, and may be modified without sacrificing the spirit of CBCS and LOCF.

1.2 Learning Outcomes-based Approach to Curricular Planning

The fundamental premise underlying the learning outcomes-based approach to curriculum planning and development is that higher education qualifications such as a Bachelor's Degree (Hons) programmes are earned and awarded on the basis of (a) demonstrated achievement of outcomes (expressed in terms of knowledge, understanding, skills, attitudes and values) and (b) academic standards expected of graduates of a programme of study.

The expected learning outcomes are used as reference points that would help formulate graduate attributes, qualification descriptors, programme learning outcomes and course learning outcomes which in turn will help in curriculum planning and development, and in the design, delivery and review of academic programmes.

Learning outcomes-based frameworks in any subject must specify what graduates completing a particular programme of study are (a) expected to know, (b) understand and (c) be able to do at the end of their programme of study. To this extent, LOCF in English is committed to allowing for flexibility and innovation in (i) programme design and syllabi development by higher education institutions (HEIs), (ii) teaching-learning process, (iii) assessment of student learning levels, and (iv) periodic programme review within institutional parameters as well as LOCF guidelines, (v) generating framework(s) of agreed expected graduate attributes, qualification descriptors, programme learning outcomes and course learning outcomes.

The key outcomes that underpin curriculum planning and development at the undergraduate level include Graduate Attributes, Qualification Descriptors, Programme Learning Outcomes, and Course Learning Outcomes.

The LOCF for undergraduate education is based on specific learning outcomes and academic standards expected to be attained by graduates of a programme of study. However, an outcome-based approach identifies moves way from the emphasis on *what is to be taught* to focus on *what is actually learnt* by way of demonstrable outcomes. This approach provides greater flexibility to the teachers to develop—and the students to accept and adopt—different learning and teaching pedagogy in an interactive and participatory ecosystem. The idea is to integrate social needs and teaching practices in a manner that is responsive to the need of the community. HEIs, on their turn, shall address to the situations of their students by identifying relevant and common outcomes and by developing such outcomes that not only match the specific needs of the students but also expands their outlook and values.

Moreover, it is borne in mind that outcome based curriculum does not obviate fact that the focus is not just on domain knowledge or outcomes only but on processes and approaches to be employed in pedagogical transactions. Processes are as important as the outcome. Else the outcomes would remain confined to the paper.

1.2.1 Nature and Extent of Bachelor's Degree Programme in English Literature (Honours)

i. Bachelor's Degree (Honours) is a well-recognized, structured, and specialized graduate level qualification in tertiary, collegiate education. The contents of this degree are determined in terms of knowledge, understanding, qualification, skills and values that a student intends to acquire in order to look for professional avenues or move to higher education at the postgraduate level.

ii. Bachelor's Degree (Honours) programmes attract entrants from the secondary level or equivalent, often with subject knowledge that may or may not be directly relevant to the particular field of study/profession. Thus, BA (Honours) Course in English aims to equip students to qualify for joining a profession or to provide development opportunities in particular employment settings. Graduates are enabled to enter a variety of jobs or to continue academic study at a higher level.

iii. Qualification descriptors at this level reflect in-depth and specialized knowledge and understanding of their subjects enriched by domain knowledge, student knowledge, critical thinking and effective communication skills. Knowledge at this level includes generic information about what all holders of the qualification are able to do, and the qualities and skills that they have. Courses, therefore, reflect different aspirations of types of students, and skills, learning needs and personal circumstances, needed thereof. Programmes assess not only academic skills but also other skills and attributes including what graduate level education requires, recognises and accredits in order for the Honours Degree to sync with national standards and be compatible with international practices.

iv. The attributes and outcomes associated with specialised programmes of study such as BA Honours in English are predominantly comprised of structured learning opportunities. These programmes are devoted to classroom learning, group and individual learning and library and field research projects. The key component in the programme is developing the ability to communicate at different levels, ranging from basic to critical communication.

v. To complete the programme of study the student needs to demonstrate knowledge of the subject, understanding of one's location, ability to critically appreciate a text or tradition in itself or in relation to others, knowledge of the development of the discipline locally and globally through classroom study, self-study and research of existing literatures and current practices. The critical perspective, thus acquired, helps the student to link the degree to life skills including professional skills and awareness with an understanding of human and literary value.

1.2.2 Aims of Bachelor's Degree Programme in English Literature (Honours)

The Honours programme in any subject is, in effect, a bridge between secondary and tertiary level education and postgraduate education. So it is important to make the courses in this programme as inclusive and broad as possible even as they also carry the imprints of specialized programmes of study. Honours courses are specialised and remain within the boundaries of accepted and current knowledge. The importance of student research is an integral part of any Honours Programme, particularly the English Honours programme.

The objectives of the LOCF in English, therefore, revisit traditional expectations of teaching and learning English by centre-staging outcomes that are demonstrable through five key attributes: understanding, use, communication, expansion, and application of subject knowledge with a clear awareness and understanding of one's location in the immediate and global environment.

In order to maximize the advantages of LOCF, the objectives are synced to outcomes. So the LOCF document highlights (i) the basic philosophy of teaching English as an Honours subject; (ii) the core objectives of English (Literary Studies and Language through Literature) by way of imparting subject knowledge, life skills, awareness of human values, respect for different locations and life forms, and professional skills; (iii) translation of each skill into demonstrable outcomes in terms of basic and critical communication, social engagement, personal growth and ability enhancement; (iv) application and use of domain knowledge as a bridge to society and the world at large; (v) demonstration of professional awareness and problem solving skills; (vi) demonstration of basic knowledge of digital knowledge platforms; (vi) ability to recognize the professional and social utility of the subject; and (vi) in the process understand, appreciate and imbibe values of life.

The broad objectives of the Learning Outcomes-based Curriculum Framework (LOCF) in English Literature (Honours) can therefore be outlined through the following points:

- **Prospects of the Curriculum:** Formulating graduate attributes, qualification descriptors, programme learning outcomes and course learning outcomes that are expected to be demonstrated by the holder of a degree student with Honours in English;

- **Core Values**: Enabling prospective students, parents, employers and others to understand the nature and level of learning outcomes (knowledge, skills, attitudes and human and literary values) or attributes for English Literature (Honours);
- **Bridge to the World**: Providing a framework to see the subject as a bridge to the world in such a way that while recognizing the different conditions in pluralistic society, the students also are aware of a core of shared values such as (i) a commitment to the knowledge to understand the world and how to make a contribution to it; (ii) development of each person's unique potential; (iii) respect for others and their rights; (iv) social and civic responsibility, participation in democratic processes; social justice and cultural diversity; and (v) concern for the natural and cultural environment;
- **Assimilation of Ability, Balance, harmony and Inclusiveness:** Identifying and defining such aspects or attributes of English Literature (Honours) that a graduate of the subject should be able to demonstrate on successful completion of the programme of study;
- **Frame for National Standards:** Providing a frame of reference for maintaining national standards with international compatibility of learning outcomes of English Literature (Honours) and academic standards to ensure global competitiveness, and to facilitate student/graduate mobility;
- **Pliability:** Formulating outcomes that are responsive to social and technological changes in order that the pedagogy will meet student's needs arising from the changes. LOCF encourages effective use of new technologies as tools for learning and provide a balance between what is common to the education of all students and the kind of flexibility and openness required for education;
- **Pedagogy:** Providing higher education institutions an important point of reference for designing teaching-learning strategies, assessing student learning levels, and periodic review of programmes and academic standards for English Literature (Honours) with shift from domain knowledge to processes of realising the outcomes;
- **Development:** Providing HEIs a developmental approach through LOCF that would accommodate social needs and provide students a clear direction of learning.

The specific objectives of the BA programme in English Literature (Honours) are to develop in the student the ability to demonstrable the following outcomes:

1. Disciplinary Knowledge of English Literature and Literary Studies
2. Communication Skills
3. Critical Thinking
4. Analytical Reasoning
5. Problem Solving
6. Research-Related Skills
7. Self-Directing Learning
8. Multicultural Competence
9. Values: Moral and Ethical, Literary and Human
10. Digital Literacy

The details are explained in the sections that follow.

1.3 Graduate Attributes

Disciplinary Knowledge:

a) ability to identify, speak and write about different literary genres, forms, periods and movements
b) ability to understand and engage with various literary and critical concepts and categories
c) ability to read texts closely, paying attention to themes, generic conventions, historical contexts, and linguistic and stylistic variations and innovations
d) ability to understand appreciate, analyze, and use different theoretical frameworks
e) ability to locate in and engage with relevant scholarly works in order to develop one's own critical position and present one's views coherently and persuasively
f) ability to situate one's own reading, to be aware of one's position in terms of society, religion, caste, region, gender, politics, and sexuality to be self-reflexive and self-questioning
g) ability to understand the world, to think critically and clearly about the local and the global through a reading of literatures in translation and in the original, to be a located Indian citizen of the world
h) ability to see and respect difference and to transcend binaries

Communication Skills:

a) ability to speak and write clearly in standard, academic English
b) ability to listen to and read carefully various viewpoints and engage with them.
c) ability to use critical concepts and categories with clarity

Critical Thinking:

a) ability to read and analyze extant scholarship
b) ability to substantiate critical readings of literary texts in order to persuade others
c) ability to place texts in historical contexts and also read them in terms of generic conventions and literary history

Problem Solving:

a) ability to transfer literary critical skills to read other cultural texts
b) ability to read any unfamiliar literary texts

Analytical Reasoning:

a) ability to evaluate the strengths and weaknesses in scholarly texts spotting flaws in their arguments
b) ability to use critics and theorists to create a framework and to substantiate one's argument in one's reading of literary texts

Research-Related Skills:

a) ability to problematize; to formulate hypothesis and research questions, and to identify and consult relevant sources to find answers
b) ability to plan and write a research paper

Teamwork and Time Management:

a) ability to participate constructively in class discussions
b) ability to contribute to group work
c) ability to meet a deadline

Scientific Reasoning:

a) ability to analyze texts, evaluating ideas and literary strategies
b) ability to formulate logical and persuasive arguments

Reflective Thinking:

ability to locate oneself and see the influence of location—regional, national, global—on critical thinking and reading

Self-Directing Learning:

a) ability to work independently in terms of reading literary and critical texts
b) ability to carry out personal research, postulate questions and search for answers

Digital Literacy:

a) ability to use digital sources, and read them critically
b) ability to use digital resources for presentations

Multicultural Competence:

a) ability to engage with and understand literature from various nations and reasons and languages
b) ability to respect and transcend differences

Moral and Ethical Values:

a) ability to interrogate one's own ethical values, and to be aware of ethical issues
b) ability to read values inherited in literary texts and criticism *vis a vis*, the environment, religion and spirituality, as also structures of power

Leadership Readiness:

ability to lead group discussions, to formulate questions for the class in literary and social texts

Life-long Learning:

a) ability to retain and build on critical reading skills
b) ability to transfer such skills to other domains of one's life and work

1.4 Qualification descriptors for a bachelor's degree with English Honours

The qualification descriptors for the BA (English Hons) programme in English shall be five learning attributes such as understanding, use, communication, expansion, and application of subject knowledge with a clear understanding of one's location. This also involves an awareness on the students' part of differences pertaining to class, caste, gender, community, region, etc. in order that they can transcend these differences with transparency of purpose and thought. The key qualification descriptor for English Honours shall be clarity of communication as well as critical thinking and ethical awareness. Each Honours Graduate in English should be able to

- *demonstrate* a coherent and systematic knowledge and understanding of the field of literary and theoretical developments in the field of English Studies and English Studies in India. This would also include the student's ability to identify, speak and write about genres, forms, periods, movements and conventions of writing as well as the ability to understand and engage with literary-critical concepts, theories and categories
- *demonstrate* the ability to understand the role of literature in a changing world from the disciplinary perspective as well as in relation to its professional and everyday use. While the aspect of disciplinary attribute is covered by the ability of the students to read texts with close attention to themes, conventions, contexts and value systems, a key aspect of this attribute is their ability to situate their reading, their position(s) in terms of community, class, caste, religion, language, region, gender, politics, and an understanding of the global and the local
- *demonstrate* the ability to think and write critically and clearly about one's role as a located Indian citizen of the world through a reading of English literatures and literatures in translation
- *Communicate* ideas, opinions and values—both literary values and values of life in all shades and shapes—in order to expand the knowledge of the subject as it moves from the classroom to life and life-worlds
- *Demonstrate* the ability to share the results of academic and disciplinary learning through different forms of communication such as essays, dissertations, reports, findings, notes, etc, on different platforms of communication such as the classroom, the media and the internet

- *Recognize* the scope of English studies in terms of career opportunities, employment and lifelong engagement in teaching, publishing, translation, communication, media, soft skills and other allied fields
- *Apply* subject-specific skills in language and literature to foster a larger sense of ethical and moral responsibility among fellow humans in order to see and respect differences in and among various species and life-forms and learn to transcend them

The programme will strengthen the student's ability to draw on narratives that alert us to layers and levels of meaning and differences in situations and complexities of relations. Linguistic and literary competence should help the students identify, analyze and evaluate keys issues in the text and around in the world—thematic, contextual, professional, processual—and think of ways to find acceptable and sustainable solutions. Students will have the ability to understand and articulate with clarity and critical thinking one's position in the world as an Indian and as an Indian citizen of the world.

1.5 Programme Learning Outcomes (BA Hons. English)

The programme learning outcomes relating to BA (Hons) degree programme in English:

- demonstrate a set of basic skills in literary communication and explication of literary practices and process with clarity
- demonstrate a coherent and systematic knowledge of the field of English literature and Bhasha literatures in English showing an understanding of current theoretical and literary developments in relation to the specific field of English studies.
- display an ability to read and understand various literary genres and stylistic variations and write critically
- cultivate ability to look at and evaluate literary texts as a field of study and as part of the wider network of local and global culture
- demonstrate a critical aptitude and reflexive thinking to systematically analyze the existing scholarship and expand critical questions and the knowledge base in the field of English studies using digital resources.
- display knowledge to cultivate a better understanding of values – both literary values that aide us in literary judgment and also values of life at all stages; apply appropriate methodologies for the development of the creative and analytical faculties of students, their overall development of writing, including imaginative writing.

- recognize employability options in English studies programme as part of skill development and as career avenues open to graduates in today's global world such as professional writing, translation, teaching English at different levels, mass media, journalism, aviation communication and personality development
- channelize the interests of the students and analytical reasoning in a better way and make more meaningful choices regarding career after completion of graduate programme
- to enable students to develop an awareness of the linguistic-cultural richness of India as an important outcome of English literary studies in India

Programme outcomes	**TABLE I : CORE COURSES (14)**																
	Indian Classical Literature	European Classical Literature	Indian Writing in English	British Poetry and Drama: 14th to 17th Centuries	American Literature	Popular Literature	British Poetry and Drama: 17th and 18th Centuries	British Literature: 18th Century	British Romantic Literature	British Literature: 19th Century	Women's Writing	British Literature: The Early 20th Century	Modern European Drama	Postcol-onial Literat-ures			
The primary programme outcomes include demonstration of subject knowledge, understanding of the field, understanding of literary movements, styles and genres, location, human values, literary sensibility and location																	
Values of life and literature	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Systematic knowledge of the field	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Knowledge of literary genres and stylistic variations	√	√	√	√			√		√	√		√	√				
Evaluation of literary texts	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Critical aptitude and reflexive thinking	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Understanding of location	√		√		√									√			
Creative and analytical application of subject knowledge to life	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√
Career Options on completion of	√	√	√		√	√					√			√			

graduate programme														
Awareness of the linguistic and cultural richness of India	√		√											√
Relating literary movements to social situations	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Use and application of Digital Knowledge Systems	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Programme outcomes	TABLE II: DISCIPLINE CENTRIC ELECTIVES (ANY FOUR)												
	Modern Indian Writing in English Translation	Literature of the Indian Diaspora	British Literature: Post World War II	Nineteenth Century European Realism	Literary Theory	Literary Criticism	Science fiction and Detective Literature	Literature and Cinema	World Literatures	Partition Literature	Research Methodology	Travel writing	Autobiography
The primary programme outcomes include application of subject knowledge to knowledge of life, knowledge of one's location in the world, human values, awareness of difference in terms of nationality, language, location, geography, literary sensibility, environment, etc. The idea is that the learner will be able to connect the subject to the world.													
Relating literary movements to social situations	√	√	√	√	√								
Systematic knowledge of the field	√	√	√	√	√	√	√	√	√	√	√	√	√
Literary genres and stylistic variations	√	√	√	√	√	√	√	√	√	√	√	√	√
Evaluation of literary texts	√	√	√	√		√	√		√	√		√	√
Critical aptitude and reflexive thinking	√	√	√	√	√	√	√	√	√	√	√	√	√
Respect for human and other species	√	√	√	√	√	√	√	√	√	√	√	√	√
Awareness of location	√	√	√		√	√		√	√	√		√	√

Career options on completion of graduate programme								√			√	√	√
Awareness of the linguistic-cultural richness of India	√	√						√	√	√	√	√	√
Application of skills in literary communication to life and society	√	√	√	√	√	√	√	√	√	√	√	√	√
Digital skills and social outreach	√	√	√	√	√	√	√	√	√	√	√	√	√

TABLE III

Programme outcomes	**TABLE III: GENERIC ELECTIVES (ANY FOUR)**						
	Academic Writing and Composition	Media and Communication Skills	Text and Performance	Language and Linguistics	Contemporary India: Women and Empowerment	Gender and Human Rights*	Language, Literature and Culture
The primary programme outcomes include application of subject knowledge as a bridge to life in the world, where the focus is on demonstrating one's competence in professional skills. These programme outcomes are directly linked to enhancement of career options/ awareness.							
Skills in communication	√	√	√	√			
Employability options	√	√	√	√			
Basic knowledge of the field	√	√		√	√	√	√
critical aptitude and reflexive thinking	√		√		√	√	√
Understanding of values and cultural difference			√		√	√	√
meaningful choices regarding career after completion of graduate programme	√	√	√	√	√	√	
an awareness of the linguistic-cultural richness of India					√	√	√
social outreach and sharing	√	√	√	√	√	√	√
digital skills and presentation of ideas	√	√	√	√	√	√	√

TABLE IV

Programme outcomes	TABLE IV: ABILITY ENHANCEMENT COURSES [ANY FOUR: 2 CORE*+ 2 ELECTIVE]						
	Environmental Study*	English/MIL Communication*	English Language Teaching	Soft Skills	Translation Studies	Creative Writing	Business Communication
The primary programme outcomes of these courses include application of subject knowledge to ability enhancement and ink directly to career options/ awareness.							
Communication skills		√	√	√	√	√	√
Knowledge of location	√	√	√	√	√	√	√
literary genres and stylistic variations			√				
Creative use of subject knowledge in a professional field	√	√	√	√	√	√	√
critical aptitude and reflexive thinking	√				√	√	
understanding of values	√				√	√	
Professional Skill and employability options	√	√	√	√	√	√	√
Career Options on completion of graduate programme	√	√	√	√	√	√	√

Personal growth and social awareness	√	√		√	√	√	√
digital skills and social outreach	√	√	√		√	√	√
systematic knowledge of the field			√		√		

1.6 The Teaching Learning Process

Learning is a challenging, engaging, and enjoyable activity. Learners should be encouraged to engage in a rigorous process of learning and self-discovery by adopting a highly focused and yet flexible approach to education as opposed to rote learning. Each day learners should be encouraged to focus on key areas of the course and spend time on learning the course fundamentals and their application in life and society. In teaching and learning pedagogy, there should be a shift from domain or conclusions based approach to the experiential or process/es based approach.

The faculty should promote learning on a proportionate scale of 20:30:50 principle, where lectures (listening/hearing) constitute 20 percent of the delivery; visuals (seeing) 30 percent of the learning methods; and experience (doing/participating) 50 percent. This ratio is subject to change as per institutional needs. In order to achieve its objective of focused process based learning and holistic development, the Institution/University may use a variety of knowledge delivery methods:

1.6.1 Lectures

Lectures should be designed to provide the learners with interesting and fresh perspectives on the subject matter. Lectures should be interactive in a way that students work with their teachers to get new insights in the subject area, on which they can build their own bridges to higher learning.

1.6.2 Discussions

Discussions are critical components of learning, and can be used as a platform for students to be creative and critical with old and new ideas. Besides developing critiquing skills, arriving at consensus on various real life issues and discussion groups lead to innovative problem solving and, ultimately to success.

1.6.3 Simulations

Simulations provide students opportunities to understand real life situations and scenarios, and solve challenges in a controlled environment or make use of them in simulating cultural experiences by locating/transposing them in new (local, regional, national and international) situations.

1.6.4 Case Studies:

Real case studies, wherever possible, should be encouraged in order to challenge students to find creative solutions to complex problems of individual, community, society and various aspects of knowledge domain concerned.

1.6.5 Role Playing

Assuming various roles, as in real life, is the key to understanding and learning. Students are challenged to make strategic decisions through role-plays, and to analyze the impact of these decisions. For this purpose, incidents from literary texts may also be used.

1.6.6 Team Work

Positive collaboration in the form of team work is critical in the classroom environment, for which it is necessary to transcend one's prejudices and predilections so as to achieve the desired outcomes. In the process of team work, leaners will acquire the skills of managing knowledge acquisition and other collaborative learners, thereby understanding how to incorporate and balance personalities.

1.6.7 Study Tours/Field Visits:

Study Tours/ Field trips provide opportunities to the learners to test their in-class learning in real life situations as well as to understand the functional diversity in the learning spaces. These may include visits to sites of knowledge creation, preservation, dissemination and application. Institutions may devise their own methods to substitute/modify this aspect.

1.7 Assessment Methods

1.7.1 Alignment of Programme Learning Outcomes and Course Learning Outcomes:

The assessment of learners' achievement in BA English (Honours) will be aligned with the following:

- programme learning outcomes (graduate descriptors)
- course learning outcomes (qualification descriptors)
- academic and professional skills suggested in the graduate learning descriptors in the LOCF recommendations (indicated and illustrated in the Learning Outcomes in respect of select courses)

1.7.2 Assessment priorities: Institutions will be required to prioritize formative assessments (in-semester activities including tests done at the department or instructor level) rather than giving heavy and final weightage to summative assessments (end-semester and/or mid-semester tests traditionally done centrally). Progress of learners towards achieving learning outcomes may be assessed making creative use of the following, either independently or in combination: time-constrained examinations (say 1-hour or 2-hour tests); closed-book and open-book tests (if applicable, rather than doing as a rule); problem based assignments; real life simulations; observation of practical skills (speaking, listening, problem solving within a peer group or a class); individual project reports (case-study or term papers within a given word limit); team project reports; oral presentations, including seminar presentation; viva voce, interviews; computerised adaptive testing for MCQ; peer and self-assessment etc. and any other pedagogic approaches as may be relevant keeping in view the learners' level, credit load and class size.

1.7.3 Diversity in Assessment Methods: Allowing for the diversity in learning and pedagogical methods adopted by different universities and institutions, stakeholders (Academic Councils, Boards of Studies or statutory bodies) are expected to ensure that the objectives of the course(s) are clearly aligned to learning outcomes. It is expected that the curricula developed by institutions will maintain a transparent roadmap of (a) pedagogical methods and priorities and (b) learning outcomes that reflect the weightage points given to different aspects of skills and achievements identified in the recommendations.

1.7.4 Learning Outcomes Index: While devising assessment modes and criteria, institutions may look to gridlock course learning outcomes and programme learning outcomes as indicated in the LOCF (English), and work out ways to assign credit loads and distribute weightage points for each. The following table shows one possible way to develop a Learning Outcomes index for the Programme and the courses.

Table							
Programme Learning outcomes	**Courses in BA Honours (English)**						
	Course 1	Course 2	Course ...	Course …	Course …	Course …	Course …
Outcome 1	x	X	x	x	x	X	X
Outcome 2	x		x	x		X	
Outcome …		X		x	x	X	x
Outcome …		X		x	x	X	
Outcome …	x		x		x		x
Outcome …	x		x		x	x	x
Outcome …		X		x		x	

1.7.5 Weightage Distribution: In-semester activities may be accorded different weightage points (say for instance, 20: 10: 10: 15: 5 out of 60 percentage points), in terms of activities such as single or group level oral components (20), individual project (10), group project (10), library and research work (15), and punctuality and regularity or any other responsibility indicator (5). Similarly, end-semester or summative assessment methods may include written tests, either written or in combination with oral components, as may be necessary, keeping in view the class size and the credit load in a given semester. Questions set in the end semester examinations may be a combination of essay type questions, short notes and objective MCQ (multiple choice questions). The credit hour distribution (L-T-O) has to be rationalized accordingly.

1.7.6 Innovation and Flexibility: Within each category, institutions are expected to encourage instructors to bring in innovative and flexible methods to guarantee the fullest realization of Learning Outcomes outlined in the document. All such instructional and assessment requirements must be clearly communicated to all stakeholders at the time of course registration. Any subsequent change or minor modification necessary for fuller realization of learning outcomes must be arranged with due notice and institutional arrangement at the relevant level.

1.7.7 Freedom and Accountability: Freedom and accountability of the stakeholder are key attributes that determine the success of the Learning Outcomes framework. For example, in research work, learners may be asked to pay attention to library work and survey of literature, originality of ideas, formulation of arguments, and creativity. Components may be assigned weightage points accordingly (say, x:y:z for different components out of 15 points). The excellence of institutions will be increasingly determined by Learning Outcomes rather than programme or course objectives. Hence it is necessary to innovate continually in learning and assessment in order to ensure meaningful and socially relevant learning (with transparent Learning Outcomes indices) rather than rote learning.

1.7.8 Clustering of Activities: Each cluster of activity may be assigned weightage points in accordance with the priorities of the institution without diluting the principles given in the LOCF. So an institution may choose to have any or all of the following in its in-semester activities with clear and transparent methods of communication to learners: open viva voce, group quiz or individual, classroom simulations and problem solving activities, library or field visits, term papers, individual and group reports, poster presentations. Credit hour and L-T-O distribution shall be crucial to any such clustering.

1.7.9 Review and Amendment: It is important for institutions to review, periodically and without fail, the efficacy of any method adopted to meet the learning outcomes proposed in the LOCF recommendations. Institutions are also required to make statutory provisions to adapt/modify/amend rules and clauses as may be necessary without violating the spirit of the larger programme outcomes outlined by the UGC in the CBCS guidelines.

1.7.10 Spirit Rather than Letter of the LOCF: The guidelines for assessment given here and elsewhere in the LOCF recommendations are indicative rather than exhaustive. So institutions are expected to frame assessment modes and criteria relevant to their situation and context, in keeping with the spirit of the LOCF. The basic idea of LOCF (English Honours)—that learners at this level should understand their position(s) in the light of regional, national and global perspectives—must find a true and transparent reflection in the assessment.

1.8 Keywords

BA Literary Studies in English (Hons.), ELT Course at UG Level, Skills and Ability Enhancement Elective Courses, Literary and human values, critical analysis and interpretation, British Poetry and Drama, British Romantic Literature, Literature of the Indian Diaspora, Media and Communication Skills, Postcolonial Literatures, British Literature: Post World War II, Travel Writing, Indian Classical Literature, European Classical Literature, Literary Criticism, Literary Theory, Indian Writing in English, Modern Indian Writing in English Translation, Translation Studies, Modern European Drama, American Literature, Popular Literature, Women's Writing, Nineteenth Century European Realism, Science Fiction and Detective Literature, Literature and Cinema, World Literatures, Partition Literature, Academic Writing and Composition, Autobiography, Text and Performance, Language and Linguistics, Contemporary India: Women and Empowerment, Gender and Human Rights, Language, Literature and Culture, English/MIL Communication, Film Studies, English Language Teaching, Soft Skills, Creative Writing, Business Communication, Technical Writing.

Part II

2.1 Structure of BA (HONS.) in English

Note: *For the structure of BA Hons. English, the Committee has followed the number of credits per course as suggested in the CBCS document, that is, six credits per course. The Committee is of the opinion that every course should be of four credits each.*

However, School/Board of Studies/University should feel free to decide the number of credits to be assigned to each course. Ultimately, what matters the most is the quantum of academic transaction assigned to each credit, not the number. The Institutions can assign and calculate the credits accordingly.

A. Core Courses: 14 papers (14x6= 84 credits) **B. Discipline Specific Electives: 4 papers (4x6= 24 credits)** **C. Generic Electives: 4 papers (4x6= 24 credits)** **D. Ability Enhancement Compulsory Courses: 2 papers (2x4=8 credits)** **E. Skill Enhancement Courses: 2 papers (2x4=8 credits)** GRAND TOTAL (A+B+C+D): 148 (84+24+24+8+8) credits			
A. CORE COURSES (14)			
Serial No	Title of the Course	Credits: 6 credits each Total 84 (credit distribution to be decided by institutions as per UGC/CBCS guidelines). [Note: While some courses may require L (5) T (2) O(0), some other courses may require L (4), T (1), and O (1)]	Credit Hours Distribution L T O L Lectures : 4 /[5]/[4] T Tutorials: 1 /[1]/(0) O Others: 1 /[0]/[2]2 [Note: There can be different options depending on the pedagogical and assessment weightage distribution]
1.	Indian Classical Literature	6	
2	European Classical Literature	6	
3	Indian Writing in English	6	
4	British Poetry and Drama: 14th to 17th Centuries	6	
5	American Literature	6	
6	Popular Literature	6	
7.	British Poetry and Drama: 17th and 18th Centuries	6	
8.	British Literature: 18th Century	6	
9	British Romantic Literature	6	

10.	British Literature: 19th Century	6	
11.	Women's Writing	6	
12.	British Literature: The Early 20th Century	6	
13.	Modern European Drama	6	
14.	Postcolonial Literatures	6	
B. DISCIPLINE SPECIFIC ELECTIVES (ANY FOUR)			
	Course title	Credits 24 (4x6) 6 credits each (credit distribution to be decided by institutions as per CBCS guidelines). [Note: While some courses may require L (5) T (2) O(0), some other courses may require L (4), T (1), and O (1)]	Credit Hours Distribution L T O L Lectures : 4 /[5]/[4] T Tutorials: 1 /[1]/(0) O Others: 1 /[0]/[2]2 [Note: There can be different options depending on the pedagogical and assessment weightage distribution]
1	Modern Indian Writing in English Translation	6	
2	Literature of the Indian Diaspora	6	
3	British Literature: Post World War II	6	
4	Nineteenth Century European Realism	6	
5	Literary Theory	6	
6	Literary Criticism	6	
7	Science fiction and Detective Literature	6	
8	Literature and Cinema	6	
9	World Literatures	6	
10	Partition Literature	6	
11	Research Methodology	6	
12	Travel writing	6	
13	Autobiography	6	
C. GENERIC ELECTIVES (ANY FOUR)			
	Course Title	Credits 24 (4x6) 6 credits each (credit distribution to be decided by institutions as per	Credit Hours Distribution L T O L Lectures : 4 /[5]/[4]

		CBCS guidelines). [Note: While some courses may require L (5) T (2) O(0), some other courses may require L (4), T (1), and O (1)]	T Tutorials: 1 /[1]/(0) O Others: 1 /[0]/[2]2 [Note: There can be different options depending on the pedagogical and assessment weightage distribution]
1	Academic Writing and Composition	6	
2	Media and Communication Skills	6	
3	Text and Performance	6	
4	Language and Linguistics	6	
5	Contemporary India: Women and Empowerment	6	
6	Gender and Human Rights*	6	
7	Language, Literature and Culture	6	
D. ABILITY ENHANCEMENT COURSES (COMPULSORY) TWO COURSES			
	PAPER TITLES	Credits 8 (2x4)	Credit Hours L T O [To be devised by institutions]
1	Environmental Study	4	
2	English/MIL Communication	4	
E. SKILL ENHANCEMENT COURSES (ANY TWO)			
	Course Titles	Credits 8 (2x4)	Credit Hours L T O [To be devised by institutions]
1	English Language Teaching	4	
2	Soft Skills	4	
3	Translation Studies	4	
4	Creative Writing	4	
5	Business Communication	4	

Note:

1. *Universities/Institutions/Departments may wish to add more courses against categories marked C, D and E, depending on the availability of specialists and other required resources.*

2. *Any major deviation from category A is likely to impact the very philosophy of LOCF in English.*

3. *Departments/Board of Studies/ Universities should have freedom to arrange papers in the order they deem fit with justification.*

4. *Whenever stakeholders seek to introduce modifications or alterations in the LOCF or CBCS guidelines, they are (a) expected to have adequate and transparent justifications to do so and (b) to notify the UGC regarding the changes and the justifications thereof.*

BA English (Honours) Courses

A. Core Courses

PAPER 1: INDIAN CLASSICAL LITERATURE

Course Level Learning Outcomes:

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- explain the eco-socio-political-cultural context of the age that produced Indian classical literature from its early beginning till 1100 AD
- appreciate the pluralistic and inclusive nature of Indian classical literature and its attributes
- historically situate the classical literature and diverse literary cultures from India, mainly from Sanskrit, but also Tamil, Prakrit and Pali by focusing on major texts in the principal genres
- trace the evolution of literary culture(s) in India in its/their contexts, issues of genres, themes and critical cultures
- understand, analyze and appreciate various texts with comparative perspectives

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

1. Excerpts from *The Ramayana*
2. Excerpts from *The Mahabharta*
3. Ilango Adigal, *Silappadikaram*
4. Bharatamuni's *Natyashastra* (Chapter 1 on the origin of drama)
5. Banabhatta, *Kadambari*
6. Kalidas, Shakuntala

Suggested Readings:

Bharata, *Natyashastra*, tr. Manmohan Ghosh, vol. I, 2nd edn. Calcutta: Granthalaya, 1967.

J.A.B. Van Buitenen, 'Dharma and Moksa', in Roy W. Perrett, ed., *Indian Philosophy*, vol. V, *Theory of Value: A Collection of Readings* (New York: Garland, 2000) pp. 33–40.

A.V. Kieth, *History of Sanskrit Literature*. Oxford: OUP, 1920.

A.K. Warder, *Indian Kavya Literature*, 8 Volumes. Delhi: Motilal Banarsidas, 2011.

PAPER 2: EUROPEAN CLASSICAL LITERATURE

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- historically situate classical European, i.e., Greek and Latin literary cultures and their socio-political-cultural contexts
- engage with classical literary traditions of Europe from the beginning till the 5th century AD
- grasp the evolution of the concept of classic and classical in the European literary thinking and its reception over a period of time
- appreciate classical literature of Europe and pursue their interests in it
- examine different ways of reading and using literary texts across a wide range of classical authors, genres and periods with comparative perspectives
- develop ability to pursue research in the field of classics
- develop academic and practical skills in terms of communication and presentation and also learn about human and literary values of classical period

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

Homer: selections from the *Illiad*
Sophocles, *Antigone* or Oedipus Rex
Virgil, selections form the *Aeneid*
Dante, selections from *The Divine Comedy*
Horace, *Satires*
Plautus: Selections from *The Ghost or Menaechmi*

Suggested Readings

Homer, *The Illiad*. Tr. E.V. Rieu. Harmondsworth: Penguin, 1985.

Sophocles, *Oedipus the King*. Tr. Robert Fagles in *Sophocles: The Three Theban Plays*. Harmondsworth: Penguin, 1984.

Richard Rutherford, *Classical Literature: A Concise History*. Oxford: Blackwell Publishing, 2005.

PAPER 3: INDIAN WRITING IN ENGLISH

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- appreciate the historical trajectory of various genres of IWE from colonial times till the present
- critically engage with Indian literary texts written in English in terms of colonialism/postcolonialism, regionalism, and nationalism
- critically appreciate the creative use of the English language in IWE
- approach IWE from multiple positions based on historical and social locations

Course Content

Some texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

NOVELS

- R.K. Narayan, *Swami and Friends*
- Amitav Ghosh, *Shadow Lines*

POETRY

- H.L.V. Derozio ‘Freedom to the Slave’, ‘The Orphan Girl’, ‘To India – My Native Land’
  Kamala Das, ‘Introduction’, ‘My Grandmother’s House’
- Nissim Ezekiel, ‘Enterprise’/ ‘Goodbye Party to Miss Pushpa TS’, ‘The Night of the Scorpion’
- Robin S. Ngangom, ‘The Strange Affair of Robin S. Ngangom’, ‘A Poem for Mother’
- Eunice de Souza, ‘De Souza Prabhu’

SHORT FICTION

- Mulk Raj Anand ‘Two Lady Rams’

- Rohinton Mistry ‘Swimming Lesson’
- Shashi Deshpande ‘The Intrusion’

DRAMA

- Mahesh Dattani, *Dance Like a Man/ Tara*

Suggested Topics for Presentation

- Indian English
- Indian English Literature and its Readership
- Themes and Contexts of the Indian English Novel
- The Aesthetics of Indian English Poetry
- Modernism in Indian English Literature
- The Nation and Indian English Literature

Suggested Readings

Raja Rao, Foreword to *Kanthapura* (New Delhi: OUP, 1989) pp. v–vi.

Salman Rushdie, ‘Commonwealth Literature does not exist’, in *Imaginary Homelands* (London: Granta Books, 1991) pp. 61–70.

Meenakshi Mukherjee, ‘Divided by a Common Language’, in *The Perishable Empire* (New Delhi: OUP, 2000) pp.187–203.

Bruce King, ‘Introduction’, in *Modern Indian Poetry in English* (New Delhi: OUP, 2nd edn, 2005) pp. 1–10.

PAPER 4: BRITISH POETRY AND DRAMA: 14TH TO 17TH CENTURIES

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- understand the tradition of English literature from 14th to 17th centuries.
- develop a clear understanding of Renaissance Humanism that provides the basis for the texts suggested
- engage with the major genres and forms of English literature and develop fundamental skills required for close reading and critical thinking of the texts and concepts
- appreciate and analyze the poems and plays in the larger socio-political and religious contexts of the time.

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

Geoffrey Chaucer *The Wife of Bath's Prologue*

Edmund Spenser Selections from *Amoretti:*

Sonnet LXVII 'Like as a huntsman...'

Sonnet LVII 'Sweet warrior...'

Sonnet LXXV 'One day I wrote her name...'

John Donne 'The Sunne Rising',

'Batter My Heart'

'Valediction: Forbidding Mourning'

Christopher Marlowe *Doctor Faustus*

William Shakespeare *Macbeth*

William Shakespeare *Twelfth Night*

Suggested Topics

- Renaissance Humanism
- The Stage, Court and City
- Religious and Political Thought
- Ideas of Love and Marriage
- The Writer in Society

Suggested Readings

Pico Della Mirandola, excerpts from the *Oration on the Dignity of Man,* in *The Portable Renaissance Reader*, ed. James Bruce Ross and Mary Martin McLaughlin (New York: Penguin Books, 1953) pp. 476–9.

John Calvin, 'Predestination and Free Will', in *The Portable Renaissance Reader,*ed. James Bruce Ross and Mary Martin McLaughlin (New York: Penguin Books,1953) pp. 704–11.

Baldassare Castiglione, 'Longing for Beauty' and 'Invocation of Love', in Book 4 of *The Courtier*, 'Love and Beauty', tr. George Bull (Harmondsworth: Penguin, rpt. 1983) pp. 324–8, 330–5.

Philip Sidney, *An Apology for Poetry*, ed. Forrest G. Robinson (Indianapolis: Bobbs-Merrill, 1970) pp. 13–18.

PAPER 5: AMERICAN LITERATURE

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- understand the depth and diversity of American literature, keeping in mind the history and culture of the United States of America from the colonial period to the present (17^{th} century to 21^{st} century)
- understand the historical, religious and philosophical contexts of the American spirit in literature; social-cultural-ecological-political contexts may, for example, include the idea of democracy, Millennial Narratives, the Myth of Success, the American Adam, the Myth of the Old South, the Wild West, Melting pot, Multiculturalism, etc.
- appreciate the complexity of the origin and reception of American literature, given its European and non-European historical trajectories, particularly in relation to writers of European (Anglo-Saxon, French, Dutch and Hispanic) descent, as well as writers from black and non-European (African, American Indian, Hispanic-American and Asian) writing traditions
- critically engage with the complex nature of American society, given its journey from specific religious obligations and their literary transformations (such as Puritanism, Unitarianism, Transcendentalism, etc.) to the growth of anti- or non-Christian sensibilities
- critically appreciate the diversity of American literature in the light of regional variations in climate, cultural traits, economic priorities
- explore and understand the nature of the relationships of human beings to other human beings and other life forms in relation to representative literary texts in various genres
- relate the African American experience in America (both ante-bellum and post-bellum) to issues of exclusion in societies relevant to their learning experience
- analyze the American mind from global and Indian perspectives and situate the American in the contemporary world

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

Fiction and Drama

Mark Twain: *Huck Finn* or Hemingway: *The Old Man and the Sea*

Or

Toni Morrison: *The Bluest Eye* or Alice Walker: *The Color Purple* or F Scott Fitzerald: *The Great Gatsby*

Arthur Miller *All My Sons* or August Wilson: *Fences*, Tennessee Williams: *The Glass Menagerie*

Short Fiction and personal narrative

Edgar Allan Poe 'The Purloined Letter'

Booker T Washington: Selection from *Up from Slavery* (Chap. 1 and 2) or Maya Angelou: Selections from *I Know Why the Caged Bird Sings* (chaps 15 and 16)

William Faulkner 'Dry September'

Poetry

Anne Bradstreet 'The Prologue'

Walt Whitman Selections from Song of Myself (Sections 1 to 5)

'O Captain, My Captain'

Emily Dickinson: Any two poems ['Because I could not stop for Death' or 'This was a Poet' or 'I heard a fly buzz']

Robert Frost: Two Poems 'Once by the Pacific'/ Mending Wall

Langston Hughes: 'The Negro Speaks of Rivers' or Maya Angelou: 'Still I Rise'

Alexie Sherman Alexie 'Crow Testament', 'Evolution'

Suggested Topics for Background Reading and Class Presentation

- The American Myths of Genesis/ The American Dream/ The American Adam
- American Romance and the American Novel
- Is *Huck Finn* the Prototypical American Novel?
- Multicultural Literature of the United States; Folklore and the American Novel
- Race and Gender in American Literature
- War and American Fiction
- Two Traditions of American Poetry; Emerson and Poe/ Typological and Tropological Traditions
- Social Realism and the American Novel
- The Questions of Form in American Poetry

Suggested Readings

Hector St John Crevecouer, 'What is an American', (Letter III) in *Letters from an American Farm*er (Harmondsworth: Penguin, 1982) pp. 66–105.

Frederick Douglass, A *Narrative of the life of Frederick Douglass* (Harmondsworth: Penguin, 1982) chaps. 1–7, pp. 47–87.

Henry David Thoreau, 'Battle of the Ants' excerpt from 'Brute Neighbours', in *Walden* (Oxford: OUP, 1997) chap. 12.

Ralph Waldo Emerson, 'Self Reliance', in *The Selected Writings of Ralph Waldo Emerson*, ed. with a biographical introduction by Brooks Atkinson (New York: The Modern Library, 1964).

Toni Morrison, 'Romancing the Shadow', in *Playing in the Dark: Whiteness and Literary Imagination* (London: Picador, 1993) pp. 29–39.

PAPER 6: POPULAR LITERATURE

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- trace the early history of print culture in England and the emergence of genre fiction and best sellers
- engage with debates on high and low culture, canonical and non-canonical literature
- articulate the characteristics of various genres of non-literary fiction
- investigate the role of popular fiction in the literary polysystem of various linguistic cultures
- demonstrate how popular literature belongs to its time
- Use various methods of literary analysis to interpret popular literature

Course Content

1. Children's Literature

   Lewis Carroll, *Through the Looking Glass*
   Sukumar Ray, Two Poems: "The Sons of Ramgaroo", and "Khichudi"

2. Detective Fiction
   Agatha Christie The Murder of Roger Ackroyd

3. Romance/Chick Lit

   Daphne du Maurier, *Rebecca*
   Or
   Anuja Chauhan, *The Zoya Factor*

4. Graphic Fiction

   Vishwajyoti Ghosh, *This Side That Side: Restorying Partition*

5. Science Fiction

   Isaac Asimov, "Nightfall"

Suggested Topics for Background Reading and Class Presentation

- Coming of Age
- The Canonical and the Popular
- Ethics and Education in Children's Literature
- Sense and Nonsense
- The Graphic Novel
- The Popular and the Market

Suggested Readings

Leslie Fiedler, 'Towards a Definition of Popular Literature', in *Super Culture: American Popular Culture and Europe*, ed. C.W.E. Bigsby

Felicity Hughes, 'Children's Literature: Theory and Practice', *English Literary History*, vol. 45, 1978,

Christopher Pawling, 'Popular Fiction: Ideology or Utopia?' in *Popular Fiction and Social Change*, ed. Christopher Pawling

Tzevetan Todorov, 'The Typology of Detective Fiction', in *The Poetics of Prose*

Darco Suvin, 'On Teaching SF Critically', in *Positions and Presuppositions in Science Fiction*

Janice Radway. 'The Institutional Matrix, Publishing Romantic Fiction', in *Reading the Romance: Women, Patriarchy, and Popular Literature*

Edmund Wilson, 'Who Cares Who Killed Roger Ackroyd?', *The New Yorker*, 20 June 1945.

Hilllary Chute, "Comics as Literature? Reading Graphic Narrative', *PMLA* 123(2)

PAPER 7: BRITISH POETRY AND DRAMA: 17TH AND 18TH CENTURIES

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- identify the major characteristics of the Comedy of Manners and Mock-Heroic poetry
- demonstrate in-depth knowledge and understanding of the religious, socio-intellectual and cultural thoughts of the 17^{th} and 18^{th} centuries
- examine critically keys themes in representative texts of the period, including Sin, Transgression, Love, Pride, revenge, sexuality, human follies, among others
- show their appreciation of texts in terms of plot-construction, socio-cultural contexts and genre of poetry and drama
- analyze literary devices forms and techniques in order to appreciate and interpret the texts

Texts suggested:

1. John Milton *Paradise Lost: Book 1*
2. John Webster *The Duchess of Malfi*
3. Aphra Behn *The Rover*
4. Alexander Pope *The Rape of the Lock*

Suggested Topics for Background Reading and Class Presentation

- Religious and Secular Thought in the 17th Century
- Changing Images of the Human Being in the Literature of the Period
- The Stage, the State and the Market
- The Mock-epic and Satire
- Women in the 17th Century
- The Comedy of Manners

Suggested Readings

The Holy Bible, *Genesis*, chaps. 1–4, *The Gospel according to St. Luke*, chaps. 1–7 and 22–4.

Niccolo Machiavelli, *The Prince*, ed. and tr. Robert M. Adams (New York: Norton, 1992) chaps. 15, 16, 18, and 25.

Thomas Hobbes, selections from *The Leviathan,* pt. I (New York: Norton, 2006) chaps. 8, 11, and 13.

John Dryden, 'A Discourse Concerning the Origin and Progress of Satire', in *The Norton Anthology of English Literature,* vol. 1, 9th edn, ed. Stephen Greenblatt (New York: Norton 2012) pp. 1767–8.

PAPER 8: BRITISH LITERATURE 18TH CENTURY

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- explain and analyze the rise of the critical mind
- trace the development of Restoration Comedy and anti-sentimental drama
- examine and analyze the form and function of satire in the eighteenth century
- appreciate and analyze the formal variations of Classicism
- map the relationship between the formal and the political in the literature of the neo-classical period

Course Content

1. William Congreve *The Way of the World*
2. Jonathan Swift *Gulliver's Travels* (Books III and IV)
3. Samuel Johnson 'London'

Thomas Gray 'Elegy Written in a Country Churchyard'

4. Laurence Sterne *The Life and Opinions of Tristram Shandy, Gentleman*

Suggested Topics and Background Prose Readings for Class Presentations

Topics

- The Enlightenment and Neoclassicism
- Restoration Comedy
- The Country and the City
- The Novel and the Periodical Press
- The Self-Conscious Art Form

Readings

Jeremy Collier, A *Short View of the Immorality and Profaneness of the English Stage* (London: Routledge, 1996).

Daniel Defoe, 'The Complete English Tradesman' (Letter XXII), 'The Great Law of Subordination Considered' (Letter IV), and 'The Complete English Gentleman', in *Literature*

and Social Order in Eighteenth-Century England, ed. Stephen Copley (London: Croom Helm, 1984).

Samuel Johnson, ‘Essay 156’, in *The Rambler*, in *Selected Writings: Samuel Johnson*, ed. Peter Martin (Cambridge, Mass.: Harvard University Press, 2009) pp. 194–7; *Rasselas* Chapter 10; ‘Pope’s Intellectual Character: Pope and Dryden Compared’, from *The Life of Pope*, in *The Norton Anthology of English Literature*, vol. 1, ed. Stephen Greenblatt, 8th edn (New York: Norton, 2006) pp. 2693–4, 2774–7.

PAPER 9: BRITISH ROMANTIC LITERATURE

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- understand Romanticism as a concept in relation to ancillary concepts like Classicism
- understand the Romantic period in English literature in terms of its social, philosophical, intellectual, literary backgrounds including German and French influences
- analyze and understand the main characteristics of Romanticism
- appreciate the canonical and representative poems and prose of the writers of the Romantic period.
- develop skills of critical analysis and interpretation of selected poems in order to understand the theme, language, style, and elements of prosody.
- appreciate and analyze the sensibility of the British Romantic period: common man, equality, freedom, sense of community and fraternity
- relate Romantic literary texts to other forms of expression such as painting, for instance.

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

1. William Blake 'The Lamb',
'The Chimney Sweeper' (from *The Songs of Innocence* and *The Songs of Experience*)
'The Tyger' (*The Songs of Experience*)
'Introduction' to *The Songs of Innocence*
Robert Burns 'A Bard's Epitaph'

'Scots Wha Hae'

2. William Wordsworth 'Tintern Abbey'
'Ode: Intimations of Immortality'
Samuel Taylor Coleridge 'Kubla Khan'
'Dejection: An Ode'

3. Lord George Gordon
Noel Byron 'Childe Harold': canto III, verses 36–45
(lines 316–405); canto IV, verses 178–86
(lines 1594–674)
Percy Bysshe Shelley 'Ode to the West Wind'
'Ozymandias'
'Hymn to Intellectual Beauty'
John Keats 'Ode to a Nightingale'
'To Autumn'
'On First Looking into Chapman's Homer'

4. Mary Shelley *Frankenstein*

Suggested Topics for Presentation

- Reason and Imagination
- Conceptions of Nature
- Literature and Revolution
- The Gothic
- The Romantic Lyric

Suggested Readings

William Wordsworth, 'Preface to Lyrical Ballads', in *Romantic Prose and* Poetry, ed. Harold Bloom and Lionel Trilling (New York: OUP, 1973) pp. 594–611.

John Keats, 'Letter to George and Thomas Keats, 21 December 1817', and 'Letter to Richard Woodhouse, 27 October, 1818', in *Romantic Prose and* Poetry, ed. Harold Bloom and Lionel Trilling (New York: OUP, 1973) pp. 766–68, 777–8.

Jean-Jacques Rousseau, 'Preface' to *Emile or Education,* tr. Allan Bloom (Harmondsworth: Penguin, 1991).

Samuel Taylor Coleridge, *Biographia Literaria*, ed. George Watson (London: Everyman, 1993) chap. XIII, pp. 161–66.

PAPER 10: BRITISH LITERATURE: 19TH CENTURY

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- identify and analyze the socio-economic-political contexts that inform the literature of the period
- comment on the historical and political awareness of literary texts as reflected in the transition from nature to culture across various genres
- understand the conflict between self and society in different literary genres of the period
- link the rise of the novel to the expansion of Colonialism and Capitalism
- understand the transition from Romantic to Victorian in literature and culture
- link the Victorian temper to political contexts in English colonies
- link the changes in the English countryside to changes brought about in similar settings in India

Course Content

1. Jane Austen *Pride and Prejudice*

2. Charlotte Bronte *Jane Eyre*

3. Charles Dickens *Hard Times*

4. Alfred Tennyson 'The Lady of Shalott'

'Ulysses'

'The Defence of Lucknow'

Robert Browning 'My Last Duchess'

'The Last Ride Together'

'Fra Lippo Lippi'

Christina Rossetti 'The Goblin Market'

Suggested Topics for Background Reading and Class Presentation

- Utilitarianism
- Colonialism and nineteenth century literature
- The Death of the Village
- The 19th Century Novel
- Marriage and Sexuality
- The Writer and Society
- Faith and Doubt
- The Dramatic Monologue

Readings:

Karl Marx and Friedrich Engels, 'Mode of Production: The Basis of Social Life', 'The Social Nature of Consciousness', and 'Classes and Ideology', in *A Reader in Marxist Philosophy*, ed. Howard Selsam and Harry Martel (New York: International Publishers,1963) pp. 186–8, 190–1, 199–201.

Charles Darwin, 'Natural Selection and Sexual Selection', in *The Descent of Man* in *The Norton Anthology of English Literature*, 8th edn, vol. 2, ed. Stephen Greenblatt (New York: Norton, 2006) pp. 1545–9.

John Stuart Mill, *The Subjection of Women* in *Norton Anthology of English* Literature, 8th edn, vol. 2, ed. Stephen Greenblatt (New York: Norton, 2006) chap. 1, pp. 1061–9.

PAPER 11: WOMEN'S WRITING

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- recognise the importance of gender specificity in literature
- understand and appreciate the representation of female experience in literature
- explain the difference between the feminine and the feminist as opposed to the female
- examine and appreciate the role played by socio-cultural-economic contexts in defining woman
- link the status of woman to social discrimination and social change
- draw a location specific trajectory of female bonding or empowerment
- to understand the complexity of social and biological constructions of manhood and womanhood
- to examine the relationship of women to work and production

Course Content

1. Emily Dickinson 'I cannot live with you'

'I'm wife; I've finished that'

Sylvia Plath 'Daddy'

'Lady Lazarus'

Eunice De Souza 'Advice to Women'

'Bequest'

2. Alice Walker *The Color Purple*

3. Charlotte Perkins Gilman 'The Yellow Wallpaper'

Katherine Mansfield 'Bliss'

Mahashweta Devi 'Draupadi', tr. Gayatri Chakravorty Spivak (Calcutta: Seagull,

2002)

4. Mary Wollstonecraft *A Vindication of the Rights of Woman* (New York: Norton, 1988)

chap. 1, pp. 11–19; chap. 2, pp. 19–38.

5. Ramabai Ranade 'A Testimony of our Inexhaustible Treasures', in *Pandita Ramabai Through Her Own Words: Selected Works*, tr. Meera Kosambi (New Delhi: OUP, 2000) pp. 295–324.

Rassundari Debi Excerpts from *Amar Jiban* in Susie Tharu and K. Lalita, eds.,

Women's Writing in India, vol. 1 (New Delhi: OUP, 1989) pp. 191–2.

Suggested Topics for Background Reading and Class Presentation

- The Confessional Mode in Women's Writing
- Sexual/Textual Politics
- Body, Beauty and Discrimination
- Race, Caste and Gender
- Social Reform and Women's Rights
- Women under Colonialism
- Women in and out of Slavery
- Is there a Woman's Language?

Suggested Readings

Virginia Woolf, *A Room of One's Own* (New York: Harcourt, 1957) chaps. 1 and 6.

Simone de Beauvoir, 'Introduction', in *The Second Sex*, tr. Constance Borde and Shiela Malovany-Chevallier (London: Vintage, 2010) pp. 3–18.

Kumkum Sangari and Sudesh Vaid, eds., 'Introduction', in *Recasting Women:Essays in Colonial History* (New Delhi: Kali for Women, 1989) pp. 1–25.

Chandra Talapade Mohanty, 'Under Western Eyes: Feminist Scholarship and Colonial Discourses', in *Contemporary Postcolonial Theory: A Reader*, ed. Padmini Mongia (New York: Arnold, 1996) pp. 172–97.

PAPER 12: BRITISH LITERATURE: THE EARLY 20TH CENTURY

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- trace the history of modernism in the socio-cultural and intellectual contexts of late nineteenth century and early twentieth century Europe
- link and distinguish between modernity and modernism
- explain the links between developments in science and experiments in literature
- explain the history of early twentieth-century modernism in the light of stream of consciousness, Jungian and Freudian ideas, Psychoanalysis, Imagism, Cubism, Vorticism
- identify and analyze the use and modernist technique in different genres in early twentieth century British literature
- trace the history of the self and subjectivity in literature in the light of colonial consciousness
- explain and analyze the idea of from in modernist literary texts from across major genres

Course Content:

1. Joseph Conrad *Heart of Darkness*

2. D.H. Lawrence *Sons and Lovers*

3. Virginia Woolf *Mrs Dalloway*

4. W.B. Yeats ‘Leda and the Swan’

‘The Second Coming’

‘No Second Troy’

‘Sailing to Byzantium’

T.S. Eliot ‘The Love Song of J. Alfred Prufrock’

‘Sweeney among the Nightingales’

‘The Hollow Men’

Suggested Topics for Background Reading and Presentation

Topics

- Modernism, Post-modernism and non-European Cultures
- The Women’s Movement in the Early 20th Century
- Psychoanalysis and the Stream of Consciousness
- Literature and the Fear of Disintegration
- The Uses of Myth
- Nation and Narration in Early Twentieth Century Novel
- The Avant Garde

Suggested Readings

Sigmund Freud, ‘Theory of Dreams’, ‘Oedipus Complex’, and ‘The Structure of the Unconscious’, in *The Modern Tradition*, ed. Richard Ellman et. al. (Oxford: OUP, 1965) pp. 571, 578–80, 559–63.

T.S. Eliot, ‘Tradition and the Individual Talent’, in *Norton Anthology of English Literature,* 8th edn, vol. 2, ed. Stephen Greenblatt (New York: Norton, 2006) pp. 2319–25.

Raymond Williams, ‘Introduction’, in *The English Novel from Dickens to Lawrence* (London: Hogarth Press, 1984) pp. 9–27.

PAPER 13: MODERN EUROPEAN DRAMA

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- understand the role of theatre and drama in the introduction and shaping of modernity
- understand and engage with concepts like realism, naturalism, symbolism, expressionism, the Avant Garde, the epic theatre, the theatre of the absurd, etc.
- understand how meaning is created in theatre and be able to write about innovations introduced into theatrical practice in the late nineteenth and the twentieth century

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

1. Henrik Ibsen, *Ghosts/ A Doll's House*
2. Bertolt Brecht, *The Good Woman of Szechuan*
3. Samuel Beckett, *Waiting for Godot*
4. Eugene Ionesco, *Rhinoceros/* Jean Genet, *The Balcony*

Suggested Topics for Presentation

- Politics, Social Change and the Stage
- Text and Performance
- European Drama: Realism and Beyond
- Tragedy and Heroism in Modern European Drama
- The Theatre of the Absurd
- The Role of the Director
- The Role of the free theatres

Suggested Readings

Constantin Stanislavski, chap. 8, ‘Faith and the Sense of Truth’, In *An Actor Prepares*, tr. Elizabeth Reynolds Hapgood (Harmondsworth: Penguin, 1967) sections 1, 2, 7, 8, 9, pp. 121–5, 137–46.

Bertolt Brecht, ‘The Street Scene’, ‘Theatre for Pleasure or Theatre for Instruction’, and ‘Dramatic Theatre vs Epic Theatre’, in *Brecht on Theatre: The Development of an Aesthetic*, ed. and tr. John Willet (London: Methuen, 1992) pp. 68–76, 121–8.

George Steiner, ‘On Modern Tragedy’, in *The Death of Tragedy* (London: Faber, 1995) pp. 303–24.

PAPER 14: POSTCOLONIAL LITERATURES

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- understand the social-historical-political-economic contexts of colonialism and postcolonialism in India and other countries affected by colonial rule
- understand the scope of postcolonial literatures in India and elsewhere, primarily as a response to the long shadow of colonialism, not just of colonial occupation
- see through a corpus of representative postcolonial texts from different colonial locations: the effects of colonial rule on the language, culture, economy and habitat of specific groups of people affected by it
- appreciate and analyze the growing spectres of inequality arising out of colonial occupation and the role played by postcolonial literatures to resist it in India and similar locations
- critically engage with issues of racism and imperialism during and after colonial occupation
- appreciate the changing role and status of English in postcolonial literatures
- link colonialism to modernity

Course Contents

1. Fiction

1. Chinua Achebe *Things Fall Apart/ Man of the People/* Amitav Ghosh: *The Hungry Tide*
2. V S Naipaul: *In a Free State* or Phakir Mohan Senapati: *Six Acres and a Third* or Rushdie: *Shame*/ or Kamila Shamsie: *In a City by the Sea* or Gabriel Garcia Marquez *Chronicle of a Death Foretold* *

2. Short Fiction

Phakir Mohan Senapati: ‘Rebati’/ Premchand/Lakshminath Bezbaroa: ‘Bapiram’]*

Bessie Head ‘The Collector of Treasures’

Ama Ata Aidoo ‘The Girl who can’

Grace Ogot ‘The Green Leaves’

3. Poetry:

Derek Walcott 'A Far Cry from Africa' /From Omeros

'Names'

Okot p'Bitek: 'My Husband'/ 'Modern Cooking'

David Malouf 'Revolving Days'

'Wild Lemons'

Mamang Dai 'Small Towns and the River'/ 'The Voice of the Mountain'

Pablo Neruda 'Tonight I can Write'/ 'The Way Spain Was'*

[Note *Attempts should be made by stakeholders to include In one or two units Indian texts in English translation that carries the imprint of colonialism and postcolonialism any of the aspects mentioned in the LOCF objectives, preferably from the region in which the course is to be taught. It is important to identify texts from Asia or Africa at the BA level, given that learners should be able to respond critically to the nature and role of colonialism in these locations]

Suggested Topic for Background Reading and Class Presentation

- Nationalism and Nationality
- De-colonization, Globalization and Literature
- Race, Region, Religion
- Women and Postcolonialism/Gender and Identity
- English and Bhasha: The Languages of Postcolonialism
- Postcolonial Literatures and Questions of Ethics
- Postcolonialism and Resistance
- Literature and Identity Politics
- Writing for the New World Audience

Suggested Readings

Franz Fanon, 'The Negro and Language', in *Black Skin, White Masks*, tr. Charles Lam Markmann (London: Pluto Press, 2008) pp. 8–27.

Ngugi wa Thiong'o, 'The Language of African Literature', in *Decolonising the Mind* (London: James Curry, 1986) chap. 1, sections 4–6.

Gabriel Garcia Marquez, the Nobel Prize Acceptance Speech, in *Gabriel Garcia Marquez: New Readings*, ed. Bernard McGuirk and Richard Cardwell (Cambridge: Cambridge University Press, 1987).

B. Discipline Centric Electives (Any Four)

PAPER 1: MODERN INDIAN WRITING IN ENGLISH TRANSLATION

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- appreciate the diversity of modern Indian literatures and the similarities between them
- understand and creatively engage with the notion of nation and nationalism
- appreciate the impact of literary movements on various Indian literatures
- critically engage with significant social issues like caste and gender
- understand the historical trajectories of Indian literatures

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

SHORT FICTION

- Premchand, 'The Shroud', in *Penguin Book of Classic Urdu Stories*, ed. M. Asaduddin (New Delhi: Penguin/Viking, 2006).
- Ismat Chugtai, 'The Quilt', in *Lifting the Veil: Selected Writings of Ismat Chugtai*, tr. M. Asaduddin (New Delhi: Penguin Books, 2009).
- Gurdial Singh, 'A Season of No Return', in *Earthy Tones*, tr. Rana Nayar (Delhi: Fiction House, 2002).
- Fakir Mohan Senapati, 'Rebati', in *Oriya Stories*, ed. Vidya Das, tr. Kishori Charan Das (Delhi: Srishti Publishers, 2000).

POETRY

- Rabindra Nath Tagore, 'Light, Oh Where is the Light?' and 'When My Play was with thee', in *Gitanjali: A New Translation with an Introduction* by William Radice (New Delhi: Penguin India, 2011).
- G.M. Muktibodh, 'The Void', (tr. Vinay Dharwadker) and 'So Very Far', (tr. Tr. Vishnu Khare and Adil Jussawala), in *The Oxford Anthology of Modern Indian Poetry*, ed.Vinay Dharwadker and A.K. Ramanujam (New Delhi: OUP, 2000).
- Amrita Pritam, 'I Say Unto Waris Shah', (tr. N.S. Tasneem) in *Modern Indian Literature: An Anthology, Plays and Prose, Surveys and Poems*, ed. K.M. George, vol. 3 (Delhi: Sahitya Akademi, 1992).
- Thangjam Ibopishak Singh, 'Dali, Hussain, or Odour of Dream, Colour of Wind' and 'The Land of the Half-Humans', tr. Robin S. Ngangom, in *The Anthology of Contemporary Poetry from the Northeast* (NEHU: Shillong, 2003).

DRAMA

- Dharamveer Bharati *Andha Yug*, tr. Alok Bhalla (New Delhi: OUP, 2009).

FICTION

G. Kalyan Rao, *Untouchable Spring*, tr. Alladi Uma and M. Sridhar (Delhi: Orient Black Swan, 2010)/ Bama, *Karukku*, tr. Lakshmi Holmstrom (Delhi: OUP, 2000)

Suggested Topics

- The Aesthetics and Politics of Translation
- Linguistic Regions and Languages
- Modernity in Indian Literature
- Caste, Gender and Resistance
- Questions of Form in 20th Century Indian Literature

Suggested Readings

Rabindranath Tagore, ‘Nationalism in India,’ in *Nationalism* (Delhi: Penguin Books, 2009) pp. 63-83.

Namwar Singh, ‘Decolonising the Indian Mind’, tr. Harish Trivedi, *Indian Literature*, No. 151 (Sept./Oct. 1992).

B.R. Ambedkar, ‘Annihilation of Caste’ in *Dr. Babasaheb Ambedkar: Writings and Speeches, vol. 1* (Maharashtra: Education Department, Government of Maharashtra, 1979) chaps. 4, 6, and 14.

Sujit Mukherjee, ‘A Link Literature for India’, in *Translation as Discovery* (Hyderabad: Orient Longman, 1994) pp. 34–45.

G.N. Devy, ‘Introduction’, from *After Amnesia* in *The G.N. Devy Reader* (New Delhi: Orient BlackSwan, 2009) pp. 1–5.

PAPER 2: LITERATURE OF THE INDIAN DIASPORA

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- understand the concept of 'diaspora' in its historical and cultural contexts
- identify different aspects of Indian diasporic consciousness and the literary features of diasporic texts
- develop a clear understanding of the formation of Indian diasporic movements within India and outside
- develop a critical understanding of the writings of the Indian diaspora within the discourse of postcoloniality, postmodernity, hybridity, globalization and transnationalism.
- develop the analytical ability to read diasporic texts and analyze key diasporic issues such as displacement, nostalgia, alienation, belonging, identity, gender, racism and assimilation
- understand the main currents of Indian diasporic narratives
- examine how texts function as diasporic markers, broadening the understanding of Indian diasporic lives, cultural practices, experiences, religion and the new medium.

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

1. M. G. Vassanji. *The Book of Secrets* (Penguin, India)
2. Rohinton Mistry. *A Fine Balance* (Alfred A Knopf)
3. Meera Syal. *Anita and Me* (Harper Collins)
4. Jhumpa Lahiri. *The Namesake* (Houghton Mifflin Harcourt)

Suggested Topics

- The Diaspora
- Nostalgia
- New Medium
- Alienation
- Globalization
- Transnationalism

Suggested Readings

"Introduction: The diasporic imaginary" in Mishra, V. (2008). *Literature of the Indian diaspora*. London: Routledge

"Cultural Configurations of Diaspora," in Kalra, V. Kaur, R. and Hutynuk, J. (2005). *Diaspora & hybridity*. London: Sage Publications.

"The New Empire within Britain," in Rushdie, S. (1991). *Imaginary Homelands*. London: Granta Books.

PAPER 3: BRITISH LITERATURE: POSTWORD WAR II

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- understand the social-historical-political-economic contexts of Post-World War II British Literature
- understand the relationship between World war II and the end of colonialism
- identify the social-historical-political changes in England after World War II
- see through a corpus of representative texts the rise of multiculturalism in England in the wake of migrations of people from colonial territories
- grasp the changing role of English in the new world order
- critically analyze and link changes in social norms to new literary forms
- engage with the idea of the postmodern and the rise of the postmodernist aesthetics
- appreciate the importance of location in understanding the self and the other

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

Fiction and non-narrative prose

1. John Fowles: *The French Lieutenant's Woman*
2. *Selections from Frank Kermode: *Untitled*/ or John Carey: *The Unexpected Professor* or Jeanette Winterson *Sexing the Cherry*

Drama and poetry

3. Hanif Kureshi *My Beautiful Launderette*
4. Poetry

    Phillip Larkin 'Whitsun Weddings'

    'Church Going'

    Ted Hughes 'Hawk Roosting'

‘Crow’s Fall’

Seamus Heaney ‘Digging’/ ‘Churning Day’/ ‘Rite of Spring’/‘Casualty’

Carol Anne Duffy ‘Text’

‘Stealing’

Suggested Topics and Background Readings and Class Presentation

- Postmodernism in British Literature
- Britishness after 1960s
- Intertextuality and Experimentation
- Literature and Counterculture
- Multiculturalism and the Rise of the Other

Readings

Alan Sinfield, ‘Literature and Cultural Production’, in *Literature*, *Politics*, *and Culture in Postwar Britain* (Berkley and Los Angeles: University of California Press, 1989), pp. 23–38.

Seamus Heaney, ‘The Redress of Poetry’, in *The Redress of Poetry* (London: Faber, 1995), pp. 1–16.

Patricia Waugh, ‘Culture and Change: 1960-1990’, in *The Harvest of The Sixties: English Literature And Its Background, 1960-1990* (Oxford: OUP, 1997

PAPER 4: NINETEENTH CENTURY EUROPEAN REALISM

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- demonstrate an awareness of the emergence of Realism and literary movements in Europe in the Nineteenth Century by engaging with key texts of European Realism.
- gain a deeper understanding of the social, economic and political conditions which gave rise to this movement.
- recognize the diversity within this broad literary movement while discerning the underlying affinities and patterns.
- examine modern reassessments of European Realism
- show an awareness of rich and complex legacy of Nineteenth Century European Realism, identify the challenges it faced and explore the causes of its decline in the Twentieth Century.

Course Contents

1. Ivan Turgenev. *Fathers and Sons* Tr Peter Carson London. Penguin 2009.
2. Fyodor Dostoyvesky. *Notes from the Underground*
3. Honore de Balzac *Old Goriot* / *Eugene Grande*
4. Guy de Maupassant *Selected Short Stories*

Suggested Topics and Background Reading for Class Presentation

- History, Realism and the Novel form
- Ethics and Fiction
- Prose, Fiction and its readership in the Nineteenth Century
- Politics and the Russian Novel: Slavophiles and Westernizers
- Portrayal of the emerging European City

Suggested Readings

Leo Tolstoy 'Man as a Creature of History' in *War and Peace* Ed Richard Ellman et.al. *The Modern Tradition* Oxford. OUP 1965 (pp 246- 54)

Honore de Balzac 'Society as Historical Organism' from the Preface to The Human Comedy in ibid (pp 265 – 67)

George Lukac, 'Balzac and Stendhal' in *Studies in European Realism.* London, Merlin Press 1972 (pp65 -85)

Harry Levin, *Gates of Horn: Study of Five French Realists.*

George Steiner 'Tolstoy or Dostoyevsky

PAPER 5: LITERARY CRITICISM

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- understand the historical and philosophical contexts that led to the development of literary criticism and its practice in different traditions and periods
- learners will be able to understand fundamental literary and critical concepts and underlying distinctions amongst them (e.g.., difference between literary criticism and literary theory)
- learners will be able to grasp a wide range of literary philosophers and critics whose works had informed and shaped the discourse of literary theory
- learners will have knowledge about major, critical movements and critics in various critical traditions – Indian(schools of *Rasa, Alamkar, Riti, Dhwani, Vakroti, Auchitya*) and Western (Greek, Roman, English, German, Russian and French)
- learners will be able to identify theoretical and critical concepts with critics/texts/movements with which they are associated and understand them in their contexts
- learners will be able to apply various theoretical frameworks and concepts to literary and cultural texts
- learners will be able to evaluate and analyze strengths and limitations of critical/theoretical frameworks and arguments
- learners will be able to strengthen and deepen their interpretative skills

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

1. Schools of Indian Literary Theory: *Rasa, Alamkar, Riti, Dhwani, Vakroti, Auchitya*
2. Aristotle (from *Poetics)*

3. Longinus: Excerpts from 'On the Sublime'
4. Christopher Caudwell Excerpts (from *Illusion and Reality)*
5. I.A. Richards: Excerpts from *Practical Criticism*
6. Victor Shklovsky (from 'Art as Technique')
7. T.S. Eliot from 'The Use of Poetry and the Use of Criticism'
8. Northrop Frye (from *The Anatomy of Criticism)*

Suggested Readings

A.H. Gilbert, *Literary Criticism: Plato to Dryden*. Detroit: Wayne University Press, 1962.

David Lodge and Nigel Wood, *Modern Criticism and Theory: A Reader*: London & New York: Routledge, 2000.

Peter Barry Beginning, *Theory: An Introduction to Literary and Cultural Theory*. Manchester: Manchester University Press, 1984.

Raman Selden, et al. *A Reader's Guide to Contemporary Literary Theory*. Kentucy: University Press of Kentucky, 1993.

S.K. Dey, *History of Poetics*. New Delhi: MLBS, 1960.

Terry Eagleton, *Literary Theory: An Introduction*. NJ: Wiley Blackwell, 2009.

PAPER 6: LITERARY THEORY

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- have a historical overview of major literary theorists, particularly of the 20^{th} century
- show an understanding of historical and philosophical contexts that led to the development of literary theory and its practices
- develop awareness of various literary theories and the way they enrich and change our thinking about language, literature and society
- historically situate literary theorists whose works had informed and shaped various literary theoretical discourses
- identify theoretical concepts with theorists and movements with which they are associated and in the process understand their contexts
- apply various theoretical frameworks and concepts to literary and cultural texts
- evaluate and analyze strengths and limitations of theoretical frameworks and arguments
- sharpen interpretative skills in the light of various theoretical frameworks

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

Module I

Literary Theory: An Introduction

Module II

New Criticism and Russian Formalism

Module III

Reader Response

Module IV

Marxism

Module V

Psychoanalytic theory

Module VI

Structuralism

Module VII

Poststructualism

Module VIII

New Historicism

Module IX

Postcolonialism

Module X

Feminism

Module XI

Black and Dalit Aesthetics/ Subaltern Studies

Module XII

Theory Now

Suggested Readings

David Lodge and Nigel Wood, *Modern Criticism and Theory: A Reader*: London & New York: Routledge, 2000.

Peter Barry Beginning, *Theory: An Introduction to Literary and Cultural Theory*. Manchester: Manchester University Press, 1984.

Raman Selden, et al. *A Reader's Guide to Contemporary Literary Theory*. Kentucy: University Press of Kentucky, 1993.

Terry Eagleton, *Literary Theory: An Introduction*. NJ: Wiley Blackwell, 2009

PAPER 7: SCIENCE FICTION AND DETECTIVE LITERATURE

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- write critically about the two genres: Science Fiction, and Detective Literature
- engage with the philosophical and psychological and social issues that are an intrinsic part to the two genres
- think through the concept of progress, and the role of technology in our life and the interaction between technology and human behaviour
- engage with the social and historical construction of crime
- analyze individual or multiple texts in the two genres in terms of key concepts including genre, implied audience, plot construction, linguistic texture, authorial identity, publication context, and sociocultural context

Course Content

1. Margaret Atwood, *The Handmaid's Tale*
2. Manjula Padmanabhan, "Escape", "Exile", "2099"
3. Arthur Conan Doyle *The Hound of the Baskervilles*
4. Kalpana Swaminathan, *The Gardener's Song*

Suggested Readings

Suvin, Darko. "On the Poetics of the Science Fiction Genre." College English 34, no. 3 (December 1972): 372–82.

Charles J. Rzepka, 'Introduction: What is Crime Fiction?', in *Companion to Crime Fiction: Blackwell Companions to Literature and Culture*, eds Charles J Rzepka and Lee Horsley (Oxford: Wiley and Blackwell, 2010) pp.1-9

Robert A. Heinlein, 'On the Writing of Speculative Fiction', online at

https://mab333.weebly.com/uploads/3/2/3/1/32314601/writing_sf_-

_01_on_the_writing_of_speculative_ficiton.pdf

Joy Palmer, 'Tracing Bodies: Gender, Genre, and Forensic Detective Fiction', *South Central Review*; Vol.18, No.3/4; *Whose Body: Recognizing Feminist Mystery and Detective Fiction* (Autumn-Winter,2001), pp.54-71.

PAPER 8: LITERATURE AND THE CINEMA

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- demonstrate a systematic and historically-grounded knowledge of literature and cinema as expressive arts
- identify and illustrate the distinction between literary and cinematic arts of storytelling
- identify and describe the difference between cinematic and literary images
- examine different theories of adaptation and link then to contexts of expression and reception
- organize different sets of activities to identify and make use of skills that distinguish the medium of cinema from that of literature
- present a coherent view of the relationship between written and cinematic texts
- communicate the role of location in adaptation

Course Content

1. James Monaco, 'The language of film: signs and syntax', in *How To Read a Film: The World of Movies, Media & Multimedia* (New York: OUP, 2009) chap. 3, pp. 170–249.

2. William Shakespeare, *Romeo and Juliet*, and its adaptations: *Romeo & Juliet* (1968; dir. Franco Zeffirelli, Paramount); and *Romeo + Juliet* (1996; dir. Baz Luhrmann, 20th Century Fox).

3. Bapsi Sidhwa, *Ice Candy Man* and its adaptation *Earth* (1998; dir. Deepa Mehta, Cracking the Earth Films Incorp.); and Amrita Pritam, *Pinjar: The Skeleton and Other Stories*, tr. Khushwant Singh (New Delhi: Tara Press, 2009) and its adaptation: *Pinjar* (2003; dir. C.P. Dwivedi, Lucky Star Entertainment).

4. Ian Fleming, *From Russia with Love*, and its adaptation: *From Russia with Love* (1963; dir. Terence Young, Eon Productions).

Suggested Topics and Background Prose Readings for Class Presentations

- Theories of Adaptation
- Transformation and Transposition
- Hollywood to 'Bollywood'
- The 'Two Ways of Seeing'
- Lost or Gained in Adaptation?
- Adaptation as Interpretation
- Classics in Fiction and Film
- Location and Adaptation in Indian Cinema
- Indian Cinema based on Western Texts
- Indian Movies based on Western Movies

Suggested Readings

Linda Hutcheon, 'On the Art of Adaptation', *Daedalus*, vol. 133, (2004).

Thomas Leitch, 'Adaptation Studies at Crossroads', *Adaptation*, 2008, vol. 1, no. 1, pp. 63–77.

Poonam Trivedi, 'Filmi Shakespeare', *Litfilm Quarterly*, vol. 35, issue 2, 2007.

Tony Bennett and Janet Woollacott, 'Figures of Bond', in *Popular Fiction: Technology, Ideology, Production, Reading*, ed. Tony Bennet (London and New York: Routledge, 1990).

PAPER 9: WORLD LITERATURES

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- explain the concept of World Literature and its evolution in relation to other related concepts e.g. national literature, general literature, comparative literature and *Vishwa Sahitya.*
- appreciate the connectedness and diversity of human experiences and literary responses to them in different parts of the world.
- analyze and appreciate literary texts from different parts of the world and receive them in the light of one's own literary traditions.
- analyze and interpret literary texts in their contexts and locate them.

Course Content:

1. Albert Camus, *The Stranger*

Or

Franz Kafka, *Metamorphosis*

2. Anton Chekov, *The Cherry Orchard*

3. Pablo Neruda, Select Poems

4. Rainer M Rilke, *Duino Elegies,*

5. Gabriel Garcia Marquez *The General in the Labyrinth*

6. Naguib Mafouz, *Palace Walk* or *Palace of Desire* (from the Cairo trilogy)

Or

Jose Saramago, *Cain*

Background Reading:

Rabindranath Tagore, *Vishwa Sahitya*, Sarkar & Sons, 1993.

David Damrosch, *How to Read World Literature*, Wiley Blackwell, 2002.

Lillian Herlands Hornhtin, *The Reader's Companion to World Literature*, Penguin, 2002.

Frank Magil, *Masterpieces of World Literature*, Collins Reference, 1991.

PAPER 10: PARTITION LITERATURE

Course Learning Outcomes

Some of the learning outcomes that learners of this course are required to demonstrate are mentioned below:

- explain historical and socio-cultural factors responsible for the Partition of Indian Sub-continent.
- demonstrate critical understanding of manifestations of the experience of the partition in various art forms.
- link and analyze the eco-socio-historical-cultural contexts and dimensions related to the Partition of India e.g. nation, nationalism, communication, violence, exile, homelessness, refugee, rehabilitation, resettlement, border and border lands (colonialism and post colonialism), literary responses to the partition in different parts of Indian continent and interpret them.
- interpret texts and experience and relate it to their contexts and experiences

Course Content:

1. Intizar Hussain, Basti, (tr), Frances W Pritchett (New Delhi: Rupa, 1995).
2. Khushwant Singh, *Train to Pakistan,* Chattos & Windus, 1956.
3. Dibyendu Palit *Alam's Own House,* tr. Sarika Chaudhary *Bengal Partition Stories: An Unclosed Chapter,* Bashabi Fraser (Ed.) London: Anthem Press (2008)
4. Sa'adat Hasan Manto, "Toba Tek Singh", in *Black Margins: Manto,* (Delhi: Katha, 2003).
5. Lalithambika Antharajanam, 'A Leaf in the Storm' (tr) K Narayanachandran, in *Stories about the Partition of India* (ed) Alok Bhalla, New Delhi, Manohar 2012 (pp 137 – 45)
6. Faiz Ahmad Faiz 'For your Lanes, My Country' in *In English* : Faiz Ahmed Faiaz, A Renowned Urdu Poet, tr and Ed Riz Ramhim. California: Xlibris 2008 (p 138)
7. Jibananda Das, 'I shall Return to This Bengal' Tr Shakunatal Chaudhuri, in *Modern Indian Literature.* New Delhi OUP

Suggested Topics and Reading for Class Presentation

Topics

- Nationalism, Colonialism, British Rule in India
- Post Colonialism in India
- Communalism and Violence
- Homelessness and Exile
- Women and Children in Partition Literature

Background Reading and Screenings

1. Ritu Menon and Kamla Bhasin, ‘Introduction’ in *Borders and Boundaries*. New Delhi, Kali for Women. 1998
2. Sukrita P Kumar, *Narrating Partition.* Delhi, Indialog 2004
3. Urvashi Butalia, *The Other Side of Silence: Voices from the Partition of India.* New Delhi, Kali for Women 2000
4. Sigmund Freud, ‘Mourning and Melancholia’ in *The Complete Psychological Works of Sigmund Freud,* Tr James Strachey. London: Hogarth Press 1953 (pp 3041 – 53)

Films

a. *Garam Hawa* (Dir. M S Sathyu, 1974))
b. *Khamosh Paani*: *Silent Waters* (Dir. Sabiha Sumar, 2003)
c. *Subarnarekha* (Dir Ritwik Ghatak, 1965)

PAPER 11: RESEARCH METHODOLOGY

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- Develop a simple questionnaire to elicit specific information.
- Collect data based on a survey and arrive at inferences using a small sample
- Discuss and draft a plan for carrying out a piece of work systematically
- Refer to authentic sources of information and document the same properly.
- Provide proper explanation for technical terms in simple language.

Course Content

a. Basic concept of research and the terminology involved
b. Basic types of research
c. Basic tools of research
d. Reference skills including skills to use dictionaries, encyclopedias, library catalogues, and net resources.
e. Stating and defending a research proposal
f. conceptualizing and drafting a research proposal
g. parts of research proposal
h. writing a research paper
i. Style manuals
j. Notes, references and bibliography
k. research and ethics: documentation and plagiarism

Suggested Readings

Kumar, Ranjit. (2012) *Research Methodology: A Step-by-Step Guide for Beginners.* New Delhi, Vikas.

Manuals of style (MLA Style Sheet, APA Style Sheet, Chicago Style Manual etc)

Wallace, Michael. (2004). *Study Skills*. Cambridge: CUP.

PAPER 12: TRAVEL WRITING

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- map the social-historical-political-economic contexts of Travel Writing from regional, national and global perspectives
- explain the origin and reception of Travel Writing in chosen locations
- appreciate and analyze the relationship of Travel Writing to colonialism
- see the link between Travel Writing and history writing: Travel Writing as an alternative history or supplement to historical writing
- see the link between travel writing and translation
- analyze travel writing in relation to colonial and postcolonial positions
- appreciate the role of travel in shaping selfhood and otherness and relate the growth of Travel Writing to regional national and global identities
- critically engage with the accounts of places visited by foreigners and how their impressions change local perspectives of the places

Course Contents

1. Ibn Batuta: 'The Court of Muhammad bin Tughlaq', Khuswant Singh's *City Improbable: Writings on Delhi*, Penguin Publisher/ Verrier Elwin: From A Philosophy for NEFA ('A Pilgrimage to Tawang')

Al Biruni: Chapter LXIII, LXIV, LXV, LXVI, in *India by Al Biruni*, edited by Qeyamuddin Ahmad, National Book Trust of India

2. Selections from Mark Twain: *The Innocent Abroad* (Chapters 7, 8, 9) or Richard Wright: Pagan Spain Ernesto Che Guevara: *The Motorcycle Diaries: A Journey around South America* (the Expert, Home land for victor, The City of Viceroys), Harper Perennial

*Selections from Vikram Seth: *Heaven Lake* or Amitav Ghosh: Dancing in Cambodia or) William Dalrymple: *City of Dijnn* (Prologue, Chapters I and II) Penguin Books

3. Rahul Sankrityayan: *From Volga to Ganga* (Translation by Victor Kierman) (Section I to Section II) Pilgrims Publishing

4. Nahid Gandhi: *Alternative Realties: Love in the Lives of Muslim Women*, Chapter 'Love, War and Widow', Westland, 2013.

Or Marianne Postans (selections from *Western India1838*) or Elizabeth Vickland (appropriate selections from *Daughter of Brahma*)

5. Elisabeth Bumiller: *May You be the Mother of a Hundred Sons: a Journey among the Women of India*, Chapters 2 and 3, pp.24-74 (New York: Penguin Books, 1991)

Suggested Topics and Background Prose Readings for Class Presentations

Topics:

- Travel Writing and Ethnography
- Gender and Travel
- Globalization and Travel
- Travel writing and Disciplinary Knowledge
- Travel and Religion
- Orientalism and Travel

Suggested Readings

Susan Bassnett, 'Travel Writing and Gender', in *Cambridge Companion to Travel Writing*, ed. Peter Hulme and Tim Young (Cambridge: CUP, 2002) pp, 225-241.

Tabish Khair, 'An Interview with William Dalyrmple and Pankaj Mishra' in *Postcolonial Travel Writings: Critical Explorations*, ed. Justin D Edwards and Rune Graulund (New York: Palgrave Macmillan, 2011), 173-184.

Casey Balton, 'Narrating Self and Other: A Historical View', in *Travel Writing: The Self and The Other* (Routledge, 2012), pp.1-29.

Sachidananda Mohanty, 'Introduction: Beyond the Imperial Eyes' in *Travel Writing and Empire* (New Delhi: Katha, 2004) pp. ix –xx.

PAPER 13: AUTOBIOGRAPHY AND LIFE WRITING

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- demonstrate a familiarity with kinds of writing which seek to represent and make sense of the experiences of the individual.
- understand the relationship between self and history, truth, claims and fiction in private and public spheres.
- explain the working of memory, politics of memory and its role in constructing identity.
- explain and analyze how life writing provides alternatives to existing ways of writing history.
- examine the status of life writing as a literary form and the history of its reception
- appreciate the emergence of life writing non-western context.

Course Content

1 .Jean-Jacques Rousseau's *Confessions* , Part I and Book 1 Tr Angela Scholar (New York. OUP 2000)

2 .M K Gandhi's *Autobiography: The Story of my Experiments with Truth* (5 – 26) Ahmedabad, Navjivan Press)

3. TJS George *MS – A Life in Music.* New Delhi, Harper Collins 2004 (first Three chapters)

4. Ramchandra Guha *Savaging the Civilized* New Delhi, Permanent Black 1999 (first three chapters)

5. *The Diary of Samuel Pepys* (selections) or The Diary of Young Girl Anne Frank

6. Richard Wright *The Black Boy (*Chapter 1 pp 1-94) Picador 1984

7. Sharan Kumar Limbale *The Outcaste* New Delhi OUP (pp 1-39)

Suggested Topics for Background Reading and Class Presentation

- Life writing and Truth
- Self and Society
- Role of memory in Life writing
- Life Writing as Resistance
- Life Writing and rewriting History
- Life Writing and Identity

Suggested Readings

Roy Pascal, *Design and Truth in Autobiography*

James Olney, 'A Theory of Autobiography' in *Metaphors of Self* Princeton University Press 1972 (pp 3 – 50)

Laura Marcus The Law of Genre in Autobiographical Discourse Manchester University Press 1994 (pp 229 – 74)

Linda Anderson, 'Introduction' in *Autobiography* London, Routledge 2001 (pp 1 – 17)

Mary G Mason, 'The Other Voice' Autobiographies of Women Wrtiters in Life/Lines Theorizing Womens' Autobiography. Ed Bella Brodzki and Celeste Shenck Cornell University Press 1988 (pp 19 – 44)

Rajkumar, Dalit *Personal Narratives*, Hyderabad, Orient Blackswan

C. Generic Elective (any four)

PAPER 1: ACADEMIC WRITING AND COMPOSITION

Course Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- convey their ideas in English using simple and acceptable English in writing
- understand to recognize and draft different types of writing – e.g. classroom notes, summaries, reports, exploratory and descriptive paragraphs, substantiating etc
- describe a diagram or elaborate information contained in a graph, chart, table etc
- write a review of a book or a movie
- write a report on an academic or cultural event that takes place in a college or university for a journal or a newspaper

Course Contents

1. Introduction to the Writing Process
2. Introduction to the Conventions of Academic Writing
3. Writing in one's own words: Summarizing and Paraphrasing
4. Study Skills including note making, note taking, information transfer, reviewing etc.
5. Structuring an Argument: Introduction, Interjection, and Conclusion
6. Critical Thinking: Syntheses, Analyses, and Evaluation
7. Remedial Grammar
8. Citing Resources; Editing, Book and Media Review

Suggested Readings

Liz Hamp-Lyons and Ben Heasley, *Study writing: A Course in Writing Skills for Academic Purposes* (Cambridge: CUP, 2006).

Renu Gupta, *A Course in Academic Writing* (New Delhi: Orient BlackSwan, 2010).

Ilona Leki, *Academic Writing: Exploring Processes and Strategies* (New York: CUP, 2nd edn, 1998).

Gerald Graff and Cathy Birkenstein, *They Say/I Say: The Moves That Matter in Academic Writing* (New York: Norton, 2009).

Eastwood, John. (2005) *Oxford Practice Grammar*. Oxford, OUP

Wallace, Michael. (2004). *Study Skills*. Cambridge, CUP

PAPER 2: MEDIA AND COMMUNICATION SKILLS

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- develop the professional ability to communicate information clearly and effectively in all kinds of environment and contexts.
- demonstrate practical skills of various types of media writing, reviews, reports, programmes and discussions.
- demonstrate their familiarity with the new media, its techniques, practices of social media and hypermedia.
- critically analyze the ways in which the media reflects, represents and influences the contemporary world.
- identify avenues for a career in print and electronic media.

Course Content

The texts suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

1. Introduction to Mass Communication

1. Mass Communication and Globalization
2. Forms of Mass Communication

Topics for Student Presentations:

a. Case studies on current issues Indian journalism

b. Performing street plays

c. Writing pamphlets and posters, etc.

2. Advertisement

1. Types of advertisements
2. Advertising ethics

3. How to create advertisements/storyboards

Topics for Student Presentations:

a. Creating an advertisement/visualization

b. Enacting an advertisement in a group

c. Creating jingles and taglines

3. Media Writing

1. Scriptwriting for TV and Radio
2. Writing News Reports and Editorials
3. Editing for Print and Online Media

Topics for Student Presentations:

a. Script writing for a TV news/panel discussion/radio programme/hosting radio programmes on community radio

b. Writing news reports/book reviews/film reviews/TV program reviews/interviews

c. Editing articles

d. Writing an editorial on a topical subject

4. Introduction to Cyber Media and Social Media

1. Types of Social Media
2. The Impact of Social Media
3. Introduction to Cyber Media

Suggested Readings

Bel, B. et al. *Media and Mediation*. New Delhi: Sage, 2005.

Bernet, John R, *Mass Communication, an Introduction*. New Jersey: Prantice Hall, 1989.

Stanley J. Baran and Davis, *Mass Communication Theory: Foundations, Ferment and Future*. Boston: Wadsworth Cengage Learning, 2012.

John Fiske, *Introduction to Communication Studies*. London: Routledge, 1982.

Katherine Miller, *Communication theories: Perspectives, Processes and Contexts*. New York: McGraw Hill, 2004.

Michael Ruffner and Michael Burgoon, *Interpersonal Communication*. New York & London: Holt, Rinehart and Winston1981.

Kevin Williams, *Understanding Media Theory*. London & New York: Bloomsbury, 2015.

V.S. Gupta, *Communication and Development*. New Delhi: Concept Publication, 2000.

PAPER 3: TEXT AND PERFORMANCE

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- distinguish between a dramatic text and a performance text
- appreciate the evolution of drama in the West and in India in terms of both, form and content, from tradition to modernity, as well as have a thorough knowledge of different theatre styles in India and the West
- to appreciate the difference between drama and other genres
- develop a comprehensive understanding of the process of performance and the entire paraphernalia involved from theatrical space and lights/sound/costume to the use of voice and body
- learn a wide variety of skills from acting and directing to script writing, costume designing, prop making and technical skills like sound and light as well as production.
- display their knowledge of different aspects of text and performance through their production and not just through theoretical knowledge.

Course Content

1. Introduction

1. Introduction to theories of Performance

2. Historical overview of Western and Indian theatre

3. Forms and Periods: Classical, Contemporary, Stylized, Naturalist

Topics for Student Presentations:

a. Perspectives on theatre and performance

b. Historical development of theatrical forms

c. Folk traditions

2. Theatrical Forms and Practices

1. Types of theatre, semiotics of performative spaces, e.g. proscenium 'in the round', amphitheatre, open-air, etc.

2. Voice, speech: body movement, gestures and techniques (traditional and contemporary), floor exercises: improvisation/characterization

Topics for Student Presentations:

a. On the different types of performative space in practice

b. Poetry reading, elocution, expressive gestures, and choreographed movement

3. Theories of Drama

1. Theories and demonstrations of acting: Stanislavsky, Brecht

2. Bharata

Topics for Student Presentations:

a. Acting short solo/ group performances followed by discussion and analysis with application of theoretical perspectives

4. Theatrical Production

1. Direction, production, stage props, costume, lighting, backstage support.

2. Recording/archiving performance/case study of production/performance/impact of media on performance processes.

Topics for Student Presentations:

a. All aspects of production and performance; recording, archiving, interviewing performers and data collection.

Suggested Readings:

Marco de Marinis, *The Semiotics of Performance*, Bloomington: Inidana University Press, 1993.

Elaine Aston, *Theatre of Sign System*, Psychology Press, 1991.

PAPER 4: LANGUAGE AND LINGUISTICS

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- recognize/understand the structure and various parts of the language
- understand the existence of language in the form of different dialects based on a set of established factors
- identify the various functions a language performs and the roles assigned to it
- understand that all languages behave alike and develop a tolerance for other languages
- understand that making errors is a process of learning and not hesitate to use language for the fear of making errors

Course Content

1. Language: language and communication; language varieties: standard and non- standard language; language change. (From Mesthrie, Rajend and Rakesh M Bhatt. 2008. *World Englishes: The study of new linguistic varieties.*Cambridge: Cambridge University Press.)

2 Structuralism:

a. Distinctive features of human language. (Here we discuss how language used for human communication though unique, shares several features with animal communication.)

b. Language learning and acquisition: (Here we discuss how a child learns language in an atmosphere of love and leisure in contrast to what happens in school. The implications this understanding will have on both learning and teaching language can be explored in brief.)

(Saussure, Ferdinand de. 1966. *Course in general linguistics.* New York: McGraw Hill 'Introduction'Chapter 3)

3 Phonology and Morphology (Akmajian, A., R. A. Demers and R, M. Harnish, *Linguistics: An Introduction to Language and Communication,* 2nd ed.; Fromkin, V., and R. Rodman, *An Introduction to Language,* 2nd ed. (New York: Holt, Rinehart and Winston, 1974) Chapters 3, 6 and 7

4 Syntax and semantics: categories and constituents phrase structure; maxims of conversation. (Akmajian, A., R. A. Demers and R, M Harnish, *Linguistics: An Introduction to Language and Communication,* 2nd ed. (Cambridge, Mass,: MIT Press, 1984; Indian edition, Prentice Hall, 1991) Chapter 5 and 6.)

Suggested Reading

Selinker, L (1975) *An Introduction to Linguistics*, London, Longman

Fromkin and Rodman. (1975) *Human and Animal Communication.* London, Pergamon.

Syal, Puspinder et.al. (2009). *An Introduction to Linguistics: Language, Grammar and Semantics*, New Delhi, PHI

Mohanraj, Jayashree. (2014) *Let's Hear them Speak*, New Delhi, Sage

PAPER 7: LANGUAGE, LITERATURE AND CULTURE

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- see literature as a fine form of expression.
- use literature for analysis to understand the use of language
- see language as a major source of transmitting culture
- show the understanding of literature in the form of extrapolation (see the relevance of a story, poem, play etc in their own lives)
- show how cultures and languages are interrelated especially through their presentation of differences .

Course Contents: *An Anthology of Writings on Diversities in India.* This is a course book prepared by the Delhi University for UG students. Appropriate contents from here and elsewhere may be selected by stakeholders keeping in view the location and neighbouring languages and cultures of the learners

E. Ability Enhancement Elective Courses (any two)

PAPER 2: ENGLISH LANGUAGE TEACHING

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- identify and classify strategies used by a teacher to teach language
- demonstrate clear understanding of the syllabus, its structure and development
- understand the structure of a textbook and its use
- articulate the reasons for different types of tests the teacher administers
- demonstrate the ways in which technology can be used for learning language.

Course Content

a. Knowing the learner (Syllabus structure; identifying the learner)
b. Structures of English language (Grammatical syllabuses and their contents)
c. Methods of teaching English language and literature
d. Materials for language teaching (Structure of a textbook and its relation to the syllabus)
e. Assessing language skills (tests and their purposes)
f. Using Technology in language learning (ICT and language learning including Web 2.0 Tools)

Suggested Reading

Penny Ur, *A Course in Language Teaching: Practice and Theory* (Cambridge: CUP, 1996).

Marianne Celce-Murcia, Donna M. Brinton, and Marguerite Ann Snow, *Teaching English as a Second or Foreign Language* (Delhi: Cengage Learning, 4th edn, 2014).

Adrian Doff, *Teach English: A Training Course For Teachers (Teacher's Workbook)* (Cambridge: CUP, 1988).

Business English (New Delhi: Pearson, 2008).

R.K. Bansal and J.B. Harrison, *Spoken English: A Manual of Speech and Phonetics*(New Delhi: Orient BlackSwan, 4th edn, 2013).

Mohammad Aslam, *Teaching of English* (New Delhi: CUP, 2nd edn, 2009).

PAPER 3: SOFT SKILLS

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- Communicate with others effectively
- Exhibit qualities of leadership
- Take responsibility to undertake a work and complete it.
- Aware of their own weaknesses
- Work in groups either as members or leaders
- Think critically or laterally and solve problems
- Be flexible to the needs of others
- Negotiate with others to solve problems (conflict resolution)
- Cope with pressure and yet produce results

Course Content

a. Effective Communication strategies
b. Self-esteem and confidence building strategies
c. Awareness of the surroundings and using the resources to the best advantage for promoting self learning.
d. Lateral thinking
e. Emotional Intelligence
f. Adaptability
g. Teamwork
h. Leadership
i. Problem solving

Suggested Readings

Mohanraj, Jayashree, (2015). *Skill Sutras: Modern Communication and Ancient Wisdom.* Bangalore, Prism Books

Raamesh, Gopalaswamy. (2010). *The ACE of Soft Skills*. New Delhi, Pearson.

Mitra, K Barun. (2012). *Personality Development and Soft Skills.* New Delhi, OUP.

PAPER 4: TRANSLATION STUDIES

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- critically appreciate the process of translation
- engage with various theoretical positions on Translation
- think about the politics of translation
- assess, compare, and review translations
- translate literary and non-literary texts

Course Content

The topics suggested here are in addition to those in the CBCS syllabus. Some texts/portions have been changed keeping in view the Course Level Learning Outcomes (CLLO) as well as global guidelines in the LOCF documents. Stakeholders, as already suggested, may make amendments in the finalization of the corpus as well as the points raised in the CLLO.

- Introducing Translation: a brief history and significance of translation in a multi linguistic and multicultural society like India.
- Exercises in different Types / modes of translation, such as:
  Different approaches to translation from fidelity to transcreation
  Functional / communicative translation
  Technical /Official translation as opposed to literary translation
  Audio-visual translation
- Introducing basic concepts and terms used in Translation Studies through relevant tasks, for example: Equivalence, Language variety, Dialect, Idiolect, Register, Style, Mode, Code mixing / Switching.
- Defining the process of translation (analysis, transference, restructuring) through critical examination of standard translated literary/non-literary texts and critiquing subtitles of English and Hindi films.
- Exercises to comprehend Equivalence in translation: Structures – equivalence between the source language and target language at the lexical (word) and syntactical

(sentence) levels. This will be done through tasks of retranslation and recreation, and making comparative study of cultures and languages.

- Translation of various kinds of short texts from short stories to news reports, poems and songs, to advertisements both print and audio-visual

Suggested Topics for Class Presentation

- Translation and Culture
- Translation and Gender
- Translation and Caste
- Idioms, and Dialects in Translation
- Understanding the aims of translation
- Evaluation of Translation

Suggested Readings

Lawrence Venuti, *Essays in The Translation Studies Reader*, London: Routledge, 2000.

Andre Lefevere, *Translation/History/Culture*: A Sourcebook, London: Routledge, 1992.

Harish Trivedi and Susan Bassnett, Introduction to *Postcolonial Translation: Theory and Practice* (London: Routledge, 1999)

Avadhesh Kumar Singh, "Translation Studies in the 21st Century", *Translation Today*, Vol. 8, Number 1, 2014, pp. 5-45.Susan Bassnett, *Translation Studies*, London: Routledge, 1998.

PAPER 5: CREATIVE WRITING

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- recognize creativity in writing and discern the difference between academic/non creative and creative writing
- develop a thorough knowledge of different aspects of language such as figures of speech, language codes and language registers so that they can both, identify as well as use these; in other words, they must learn that creative writing is as much a craft as an art
- develop a comprehensive understanding of some specific genres such as fiction, poetry, drama and newspaper writing
- distinguish between these as well as look at the sub divisions within each genre(such as in poetry, different forms like sonnets, ballads, haiku, ghazal, etc)
- process their writing for publication and so must have the ability to edit and proofread writing such that it is ready to get into print.

Course Content

Unit 1. What is Creative Writing?

Unit 2. The Art and Craft of Writing

Unit 3. Modes of creative Writing

Unit 4. Writing for the Media

Unit 5. Preparing for Publication

Suggested Readings

Dev, Anjana Neira (2009). *Creative Writing: A Beginner's Manual*. Pearson, Delhi, 2009.

Morley, David (2007). *The Cambridge Introduction to Creative Writing.* Cambridge, New York.

PAPER 6: BUSINESS COMMUNICATION

Course Level Learning Outcomes

Some of the course learning outcomes that students of this course are required to demonstrate run thus:

- develop a comprehensive understanding of the theoretical and practical aspects of business communication
- develop both basic and advanced skills in business communication from writing minutes of meetings to project reports
- demonstrate through their speech and writing, appropriate business communication
- communicate at different levels of social and receptive domains
- perform appropriate roles of business personnel in different locations

Course Content:

1. Introduction to the Essentials of Business Communication: Theory and practice
2. Citing references, and using bibliographical and research tools
3. Writing a project report
4. Writing reports on field work/visits to industries, business concerns etc. /business negotiations.
5. Summarizing annual report of companies
6. Writing minutes of meetings
7. E-correspondence
8. Spoken English for business communication

   (Viva for internal assessment)
9. Making oral presentations

   (Viva for internal assessment)

Suggested Readings:

Scot, O.; Contemporary *Business Communication*. Biztantra, New Delhi.

Lesikar, R.V. & Flatley, M.E.; *Basic Business Communication Skills for Empowering the Internet Generation*, Tata McGraw Hill Publishing Company Ltd. New Delhi.

Ludlow, R. & Panton, F.; *The Essence of Effective Communications*, Prentice Hall of India Pvt. Ltd., New Delhi.

R. C. Bhatia, *Business Communication*, Ane Books Pvt Ltd, New Delhi

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Expert Committee Members of Learning Outcomes based Curriculum Framework (LOCF) English

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Learning Outcomes based Curriculum Framework (LOCF)

for

Undergraduate Programme

B.Sc. (Physics)

2019

ज्ञान-विज्ञान विमुक्तये

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.

DPSingh

New Delhi
30th July, 2019

(Prof. D. P. Singh)
Chairman
University Grants Commission

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Preamble

The role of higher education is very important in securing the gainful employment and / or providing further access to higher education comparable to the best available in the world class institutions elsewhere. The improvement in the quality of higher education, therefore, deserves to be given highest priority to enable the young generation of students to acquire skill, training and knowledge in order to enhance their thinking, comprehension and application abilities and prepare them to compete, succeed and excel globally. Sustained initiatives are required to reform the present higher education system for improving and upgrading the academic resources and learning environments by raising the quality of teaching and standards of achievements in learning outcomes across all undergraduate programs in science, humanities, commerce and professional streams of higher education. One of the significant reforms in the undergraduate education is to introduce the Learning Outcomes-based Curriculum Framework (LOCF) which makes it student -centric, interactive and outcome-oriented with well defined aims, objectives and goals to achieve. The University Grants Commission (UGC) took the initiative of implementing the LOCF in the Colleges and the Universities of the country and Prof. D P Singh, the honourable chairman constituted a Core Expert Committee (CEC) which formulated the modalities for developing the LOCF in various subjects being taught in the undergraduate courses in sciences, humanities and commerce. The honourable chairman also constituted the Subject Expert Committees (SEC) in various subjects to prepare detailed guidelines for the LOCF in subjects concerned. The following Committee was constituted in Physics.

1. Prof. S.K.Singh (Former Vice Chancellor HNB Garhwal University) – Chairman
2. Prof. M.R. Anantharaman, Dept. of Physics, Cochin University of Science and Technology, Kochi – member
3. Prof. Buddhadeb Ghosh, Dept. of Physics, The University of Burdwan -member
4. Prof. C.N. Kumar, Dept. of Physics, Panjab University, Chandigarh – member

A meeting of the members of the CEC and all the Chairmen of SEC was held on 18.06.2018 which was chaired by Prof. D P Singh and attended by Prof R. Jain, Secretary UGC, Dr. R. Batra, Additional Secretary, UGC and Ms. M. Kaushik, The Education Officer, UGC, Prof. K. Ramachandran, a member of the CEC made a presentation on the essential features of the LOCF which was formulated on the basis of a set of learning outcomes projected to be achieved for enhancing the employability and providing further opportunities for higher education and research. These Learning Outcomes (LO) determine the structure of the under graduate programs to be offered by the Higher Educational Institutions (HEI) of our country. The key components of the planning and development of LOCF are given in terms of clear and unambiguous description of the Graduate Attributes, Qualification descriptors, Program Learning Outcomes(PLO) and Course Learning Outcomes(CLO) to be achieved at the end of the successful completion of each undergraduate program to be offered by the HEI.

In the undergraduate education in physics there are two undergraduate programs leading to the degree of B. Sc. with Physics and B. Sc (Honours) Physics. The Course Learning Outcomes (CLO) are defined separately for both programs.

In order to formulate the LOCF in physics, the first meeting of the Committee was held on 6th August 2018 at UGC, New Delhi. The Chairman briefed the members about the decisions taken in the meeting of all the chairmen of SEC with the members of CEC and officers of UGC held on 18.06.2018 and appraised them the task at hand and the modalities to prepare the report were elucidated. The topics were allocated to each member keeping in mind the member's expertise and interests. It was proposed that the prepared notes shall be circulated among all members for feedback in the first instance.

Prof. A. C. Pandey, Director, IUAC, New Delhi was co-opted as member to the committee to utilize his expertise with his broad background in Physics, specialization in experimental physics and his experience as director of Institute of Interdisciplinary Studies, Allahabad.

The second meeting of the Committee was held on 24th September at UGC, New Delhi. Prof. Singh, Chairperson, briefed about the UGC meeting he attended along with Chairmen of all subject LOCF Committees, Prof. D P Singh, Chairman UGC, R. Subramaniam, Secretary MHRD and other officers of UGC and MHRD on 18.09.2018. The committee reviewed the progress made in the preparation of LOCF. It was resolved that all the inputs and the individual contributions be collated and discussed through the exchange of e-mails, telephonic conversions and other means of communications and resolved to finalize the draft report at the earliest possible date. Meanwhile UGC invited suggestions / comments from interested Institutions /

faculty to provide valuable feedback with reference to CBCS / LOCF program. About a dozen suggestions were received by various teachers and scientists working in many institutions in India which were made available to the committee and were given serious considerations in preparing the report.

The committee in its meetings deliberated on all the undergraduate programs being offered in physics which are categorized in two distinct types of programs.

1. i) B.Sc (Honours) Physics
2. ii)B.Sc with Physics

   iii) B.Sc with Physics, Chemistry, Mathematics i.e., B.Sc (PCM)

   iv) B.Sc with Physics, Electronics, Mathematics i.e., B.Sc (PEM)

   v) B.Sc with Physics, Mathematics, Computer Science i.e., B.Sc (PMC)

The LOCF have been formulated for the above courses as far as the Qualification Descriptors, Program Learning Outcomes (PLO) and the Course Learning Outcomes (CLO) are concerned.

Once the LOCF are formulated for the two undergraduate programs, their course structure and detailed contents of the courses regarding the various components like the class room teaching (theory), laboratory (experiments), tutorials, and industrial / field visits and projects can be designed and planned to achieve the stated Learning Objectives (LO).

The LOCF also gives general guidelines for the teaching-learning process (TLP) corresponding to each component of theory, experiment, tutorials, projects and industrial / field visits to be followed in order to achieve the stated outcomes for each component. Finally some suggestions for using various methods in the assessment and evaluation of learning levels of students are also made.

Learning Outcomes-Based Curriculum Framework for undergraduate education in Physics

1. Introduction

The learning outcomes-based curriculum framework (LOCF) for the undergraduate programs in Physics like B.Sc(Physics) and B.Sc.(Honours) in Physics is intended to provide a broad framework within which both the undergraduate programs in Physics help to create an academic base that responds to the need of the students to understand the basics of Physics and its ever evolving nature of applications in explaining all the observed natural phenomenon as well as predicting the future applications to the new phenomenon with a global perspective. The curriculum framework is designed and formulated in order to acquire and maintain standards of achievement in terms of knowledge, understanding and skills in Physics and their applications to the natural phenomenon as well as the development of scientific attitudes and values appropriate for rational reasoning, critical thinking and developing skills for problem solving and initiating research which are competitive globally and are on par in excellence with the standard Higher Education Institutions (HEI) in the advanced countries of America, Asia and Europe. The multicultural fabric of our nation requires that the institutions involved in implementing this curriculum framework also work hard towards providing an environment to create, develop and inculcate rational, ethical and moral attitudes and values to help the creation of knowledge society needed for scientific advancement of our nation.

The learning outcome based curriculum framework in Physics should also allow for the flexibility and innovation in the program design of the UG education, and its syllabi development, teaching learning process and the assessment procedures of the learning outcomes. The process of learning is defined by the following steps which should form the basis of final assessment of the achievement at the end of the program.

- The accumulation of facts of nature and the ability to link the facts to observe and discover the laws of nature i.e. develop an understanding and knowledge of the basic Physics.
- The ability to use this knowledge to analyze new situations and learn skills and tools like mathematics, engineering and technology to find the solution, interpret the results and make predictions for the future developments.
- The ability to synthesize the acquired knowledge, understanding and experience for a better

and improved comprehension of the physical problems in nature and to create new skills and tools for their possible solutions.

The conceptualization and formulation of the learning outcomes for an undergraduate program in Physics is aimed to achieve (i) and (ii) above while the (iii) could be planned for the PG and research programs in Physics in the Higher Education Institutions in India.

2. Learning Outcomes based approach to Curriculum planning

2.1 Nature and extent of UG program in Physics:

The UG programs in Physics builds on the basic Physics taught at the +2 level in all the schools in the country. Ideally, the +2 senior secondary school education should aim and achieve a sound grounding in understanding the basic Physics with sufficient content of topics from modern Physics and contemporary areas of exciting developments in physical sciences to ignite the young minds. The curricula and syllabi should be framed and implemented in such a way that the basic connection between theory and experiment and its importance in understanding Physics should be apparent to the student. This is very critical in developing a scientific temperament and urge to innovate, create and discover in Physics. Unfortunately the condition of our school system in most parts of the country lacks the facilities to achieve the above goal and it is incumbent upon the college/university system to fill the gaps in the knowledge creation of our young minds created by the lack of infrastructural and academic resources of our school system and strengthen their understanding in all the subjects through the UG programs specially in Physics and other science subjects.

The undergraduate program in Physics is presently being offered though the courses designed for granting the following degrees by various colleges and universities in India. All the courses are of three year duration spread over six semesters after the higher secondary (+2) level Physics course.

i. B.Sc (Honours) Physics
ii. B.Sc with Physics
iii. B.Sc with Physics, Chemistry, Mathematics i.e., B.Sc (PCM)
iv. B.Sc with Physics, Electronics, Mathematics i.e., B.Sc (PEM)
v. B.Sc with Physics, Mathematics, Computer Science i.e., B.Sc (PMC)

2.2 Aims of UG program in Physics.

The aims and objectives of our UG educational programs in sciences in general and Physics in particular should be structured to

- create the facilities and environment in all the educational institutions to consolidate the knowledge acquired at +2 level and to motivate and inspire the students to create deep interest in Physics, to develop broad and balanced knowledge and understanding of physical concepts, principles and theories of Physics.
- learn, design and perform experiments in the labs to demonstrate the concepts, principles and theories learned in the classrooms.
- develop the ability to apply the knowledge acquired in the classroom and laboratories to specific problems in theoretical and experimental Physics.
- expose the student to the vast scope of Physics as a theoretical and experimental science with applications in solving most of the problems in nature spanning from 10^{-15} m to 10^{26}m in space and 10^{-10} eV to 10^{25}eV in energy dimensions.
- emphasize the discipline of Physics to be the most important branch of science for pursuing the interdisciplinary and multidisciplinary higher education and/or research in interdisciplinary and multidisciplinary areas.
- to emphasize the importance of Physics as the most important discipline for sustaining the existing industries and establishing new ones to create job opportunities at all levels of employment.

In view of opening the new windows in higher education and research and opening job opportunities at all levels from technicians to innovator scientists and engineers, two undergraduate programs are offered in our universities and other higher education institutions (HEI) at the entry level of our higher education system.

3. Graduate attributes in Physics

Some of the characteristic attributes of a graduate in Physics are

- **Disciplinary knowledge and skills:** Capable of demonstrating

  (i) good knowledge and understanding of major concepts, theoretical principles and experimental findings in Physics and its different subfields like Astrophysics and Cosmology, Material science, Nuclear and Particle Physics, Condensed matter Physics, Atomic and Molecular Physics, Mathematical Physics, Analytical dynamics, Space science and other related fields of study, including broader interdisciplinary subfields like Chemistry, Mathematics, Life sciences, Environmental sciences, Atmospheric Physics, Computer science, Information Technology etc.

(ii) ability to use modern instrumentation and laboratory techniques to design and perform experiments is highly desirable in almost all the fields of Physics listed above in (i).

- **Skilled communicator:** Ability to transmit complex technical information relating all areas in Physics in a clear and concise manner in writing and oral ability to present complex and technical concepts in a simple language for better understanding.
- **Critical thinker and problem solver:** Ability to employ critical thinking and efficient problem solving skills in all the basic areas of Physics.
- **Sense of inquiry:** Capability for asking relevant/appropriate questions relating to the issues and problems in the field of Physics, and planning, executing and reporting the results of a theoretical or experimental investigation.
- **Team player/worker**: Capable of working effectively in diverse teams in both classroom, laboratory, Physics workshop and in industry and field-based situations.
- **Skilled project manager:** Capable of identifying/mobilizing appropriate resources required for a project, and manage a project through to completion, while observing responsible and ethical scientific conduct; and safety and laboratory hygiene regulations and practices.
- **Digitally Efficient*:*** Capable of using computers for simulation studies in Physics and computation and appropriate software for numerical and statistical analysis of data, and employing modern e-library search tools like Inflibnet, various websites of the renowned Physics labs in countries like the USA, Europe, Japan etc. to locate, retrieve, and evaluate Physics information.
- **Ethical awareness / reasoning*:*** The graduate should be capable of demonstrating ability to think and analyze rationally with modern and scientific outlook and identify ethical issues related to one's work, avoid unethical behavior such as fabrication, falsification or misrepresentation of data or committing plagiarism, not adhering to intellectual property rights, and adopting objectives, unbiased and truthful actions in all aspects of work.

- **National and international perspective*:*** The graduates should be able to develop a national as well as international perspective for their career in the chosen field of the academic activities. They should prepare themselves during their most formative years for their appropriate role in contributing towards the national development and projecting our national priorities at the international level pertaining to their field of interest and future expertise.
- **Lifelong learners:** Capable of self-paced and self-directed learning aimed at personal development and for improving knowledge/skill development and reskilling in all areas of Physics.

4. Qualification descriptors for a UG programs in Physics

4.1 Qualification descriptors for a B.Sc General, B.Sc (PCM), B.Sc (PEM), B.Sc (PMC)

The qualification descriptors for a B.Sc General, B.Sc (PCM), B.Sc (PEM), B.Sc (PMC) program may include the following.

The graduates should be able to:

- Demonstrate

  (i) a fundamental/systematic or coherent understanding of the academic field of Physics, its different learning areas like Astrophysics, Material science, Nuclear and Particle Physics, Condensed matter Physics, Atomic and Molecular Physics, Mathematical Physics, Analytical dynamics, Space science and applications, and its linkages with related disciplinary areas/subjects like Chemistry, Mathematics, Life sciences, Environmental sciences, Atmospheric Physics, Computer science, Information Technology;

  (ii) procedural knowledge that creates different types of professionals related to different areas of study in Physics outlined above, including research and development, teaching and government and public service;

  (iii) skills in areas related to specialization area relating the subfields and current developments in the academic field of Physics.

- Use knowledge, understanding and skills required for identifying problems and issues relating to Physics, collection of relevant quantitative and/or qualitative data drawing on a wide range of sources from various Physics laboratories of the world, and their application, analysis and evaluation using methodologies as appropriate to Physics for formulating new theories and concepts.

- Communicate the results of studies undertaken accurately in a range of different contexts using the main concepts, constructs and techniques of Physics. Develop communication abilities to present these results in technical as well as popular science meetings organized in various universities and other private organizations.
- Ability to meet one's own learning needs, drawing on a range of current research and development work and professional materials, and interaction with other physicists around the world.
- Apply one's knowledge of Physics and theoretical and laboratory skills to new/unfamiliar contexts to identify and analyse problems and issues and solve complex problems in Physics and related areas with well-defined solutions.
- Demonstrate Physics-related technological skills that are relevant to Physics-related job trades and employment opportunities.

4.2 Qualification descriptors for a B.Sc (Honours)

The qualification descriptors for a B.Sc(Honours) Physics Program may include the following. The graduates should be able to:

- Demonstrate

  (i) a systematic, extensive and coherent knowledge and understanding of the academic field of study as a whole and its applications, and links to related disciplinary areas/subjects of study; including a critical understanding of the established theories, principles and concepts, and of a number of advanced and emerging issues in the field of Physics;
  (ii) procedural knowledge that creates different types of professionals related to the subject area of Physics, including research and development, teaching and government and public service;
  (iii) skills in areas related to one's specialization area and current developments in the academic field of Physics, including a critical understanding of the latest developments in the area of specialization, and an ability to use established techniques of analysis and enquiry within the area of specialization.
- Demonstrate comprehensive knowledge about materials, including current research, scholarly, and/or professional literature, relating to essential and advanced learning areas pertaining to various subfields in Physics, and techniques and skills required for identifying Physics

problems and issues in their area of specialization in Physics.

- Demonstrate skills in identifying information needs, collection of relevant quantitative and/or qualitative data drawing on a wide range of sources from the Physics labs around the world, analysis and interpretation of data using methodologies as appropriate to the subject of Physics in the area of his specialization.
- Use knowledge, understanding and skills in Physics for critical assessment of a wide range of ideas and complex problems and issues relating to the various sub fields of Physics.
- Communicate the results of studies undertaken in the academic field of Physics accurately in a range of different contexts using the main concepts, constructs and techniques of the subject of Physics;
- Address one's own learning needs relating to current and emerging areas of study relating to Physics, making use of research, development and professional materials as appropriate, including those related to new frontiers of knowledge in Physics.
- Apply one's knowledge and understandings relating to Physics and skills to new/unfamiliar contexts and to identify and analyze problems and issues and seek solutions to real-life problems.
- Demonstrate subject-related and transferable skills that are relevant to some of the Physics-related jobs and employment opportunities.

5. Programme learning outcomes relating to B.Sc Courses in Physics

5.1 Program Learning Outcomes in B.Sc General, B.Sc (PCM), B.Sc (PEM), B.Sc (PMC)

The student graduating with the Degree B.Sc General, B.Sc (PCM), B.Sc (PEM), B.Sc (PMC) should be able to

- Acquire

  (i) a fundamental/systematic or coherent understanding of the academic field of Physics, its different learning areas and applications in basic Physics like Astrophysics, Material science, Nuclear and Particle Physics, Condensed matter Physics, Atomic and Molecular Physics, Mathematical Physics, Analytical dynamics, Space science, and its linkages with related disciplinary areas / subjects like Chemistry, Mathematics, Life sciences, Environmental sciences, Atmospheric Physics, Computer science, Information Technology;

(ii) procedural knowledge that creates different types of professionals related to the disciplinary/subject area of Physics, including professionals engaged in research and development, teaching and government/public service;

(iii) skills in areas related to one's specialization area within the disciplinary/subject area of Physics and current and emerging developments in the field of Physics.

- Demonstrate the ability to use skills in Physics and its related areas of technology for formulating and tackling Physics-related problems and identifying and applying appropriate physical principles and methodologies to solve a wide range of problems associated with Physics.
- Recognize the importance of mathematical modeling simulation and computing, and the role of approximation and mathematical approaches to describing the physical world.
- Plan and execute Physics-related experiments or investigations, analyze and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories of Physics.
- Demonstrate relevant generic skills and global competencies such as (i) problem-solving skills that are required to solve different types of Physics-related problems with well-defined solutions, and tackle open-ended problems that belong to the disciplinary-area boundaries; (ii) investigative skills, including skills of independent investigation of Physics-related issues and problems; (iii) communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature; (iv) analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to Physics and ability to translate them with popular language when needed; (v) ICT skills; (vi) personal skills such as the ability to work both independently and in a group.
- Demonstrate professional behavior such as (i) being objective, unbiased and truthful in all aspects of work and avoiding unethical, irrational behavior such as fabricating, falsifying or misrepresenting data or committing plagiarism; (ii)the ability to identify the potential ethical issues in work-related situations; (iii) appreciation of intellectual property, environmental and

sustainability issues; and (iv) promoting safe learning and working environment.

5.2 Program Learning Outcomes in B.Sc (Honours) Physics

The student graduating with the Degree B.Sc (Honours) Physics should be able to

- Acquire

  (i) a fundamental/systematic or coherent understanding of the academic field of Physics, its different learning areas and applications in basic Physics like Astrophysics, Material science, Nuclear and Particle Physics, Condensed matter Physics, Atomic and Molecular Physics, Mathematical Physics, Analytical dynamics, Space science, and its linkages with related disciplinary areas/subjects like Chemistry, Mathematics, Life sciences, Environmental sciences, Atmospheric Physics, Computer science, Information Technology;

  (ii) procedural knowledge that creates different types of professionals related to the disciplinary/subject area of Physics, including professionals engaged in research and development, teaching and government/public service;

  (iii) skills in areas related to one's specialization area within the disciplinary/subject area of Physics and current and emerging developments inthe field of Physics.
- Demonstrate the ability to use skills in Physics and its related areas of technology for formulating and tackling Physics-related problems and identifying and applying appropriate physical principles and methodologies to solve a wide range of problems associated with Physics.
- Recognize the importance of mathematical modeling simulation and computing, and the role of approximation and mathematical approaches to describing the physical world.
- Plan and execute Physics-related experiments or investigations, analyze and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories of Physics.
- Demonstrate relevant generic skills and global competencies such as

  (i) problem-solving skills that are required to solve different types of Physics-related problems with well-defined solutions, and tackle open-ended problems that belong to the disciplinary-area boundaries;

(ii) investigative skills, including skills of independent investigation of Physics-related issues and problems;

(iii) communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature;

(iv) analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to Physics and ability to translate them with popular language when needed;

(v) ICT skills;

(vi) personal skills such as the ability to work both independently and in a group.

- Demonstrate professional behavior such as

  (i) being objective, unbiased and truthful in all aspects of work and avoiding unethical, irrational behavior such as fabricating, falsifying or misrepresenting data or committing plagiarism;

  (ii) the ability to identify the potential ethical issues in work-related situations;

  (iii) appreciation of intellectual property, environmental and sustainability issues; and

  (iv) promoting safe learning and working environment.

Core Course for B.Sc (Hons.)

S. No.		CC-I	CC-II	CC-III	CC-IV	CC-V	CC-VI	CC-VII	CC-VIII	CC-IX	CC-X	CC-XI	CC-XII	CC-XIII	CC-XIV
1	Fundamental understanding of the field	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	Application of basic Physics concepts	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	Linkages with related disciplines	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	Procedural knowledge for professional subjects	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	Skills in related field of specialization	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6	Ability to use in Physics problem	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	Skills in Mathematical modeling	X	X	X	X	X	_	_	X	_	_	X	X	X	X
8	Skills in performing analysis and interpretation of data	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9	Develop investigative Skills	X	X	X	X	X	X	X	X	_	X	X	X	X	X
10	Skills in problem solving in Physics and related discipline	X	X	X	X	X	X	X	X	X	X	X	X	X	X
11	Develop Technical Communication skills	X	X	X	X	-	-	X	X	X	X	X	X	X	X
12	Developing analytical skills and popular communication	X	X	X	X	-	-	-	-	X	_	_	X	X	X
13	Developing ICT skills	X	X	X	X	X	X	X	X	_	X	X	X	X	X
14	Demonstrate Professional behaviour with respect to attribute like objectivity, ethical values, self reading, etc	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Discipline Specific Electives (DSE) forB.Sc. (Hons.)

S. No		DSE -I	DSE -II	DSE -III	DSE -IV	DSE -V	DSE -VI	DSE -VII	DSE -VIII	DSE -IX	DSE -X	DSE -XI	DSE -XII	DSE -XIII	DSE -XIV
1	Fundamental understanding of the field	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	Application of basic Physics concepts	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	Linkages with related disciplines	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	Procedural knowledge for professional subjects	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	Skills in related field of specialization	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6	Ability to use in Physics problem	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	Skills in Mathematical modeling	-	-	-	X	X	X	X	-	-	X	-	-	-	X
8	Skills in performing analysis and interpretation of data	X	X	X	X	X	-	-	-	X	X	X	X	-	X
9	Develop investigative Skills	X	-	-	X	X	X	X	-	-	-	-	-	-	X
10	Skills in problem solving in Physics and related discipline	X	-	-	X	X	X	X	-	X	-	X	X	X	X
11	Develop Technical Communication skills	-	-	X	X	-	-	-	-	X	X	X	-	-	-
12	Developing analytical skills and popular communication	-	-	X	-	-	-	-	-	X	X	X	-	-	-
13	Developing ICT skills	-	X	-	X	-	X	X	X	-	-	-	-	-	X
14	Demonstrate Professional behaviour with respect to attribute like objectivity, ethical values, self reading, etc	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Skill Enhancement Course (SEC) for B.Sc. (Hons.) and B.Sc. Regular

S. No.		SEC -I	SEC -II	SEC -III	SEC -IV	SEC -V	SEC -VI	SEC -VII	SEC -VIII	SEC -IX
1	Fundamental understanding of the field	X	X	X	X	X	X	X	X	X
2	Application of basic Physics concepts	X	X	X	X	X	X	X	X	X
3	Linkages with related disciplines	X	X	X	X	X	X	X	X	X
4	Procedural knowledge for professional subjects	-	X	X	X	X	-	-	X	X
5	Skills in related field of specialization	-	-	-	X	-	-	-	X	X
6	Ability to use in Physics problem	-	X	X	-	-	X	X	X	-
7	Skills in Mathematical modeling	-	X	-	-	-	-	-	-	X
8	Skills in performing analysis and interpretation of data	X	X	X	X	X	X	X	X	X
9	Develop investigative Skills	X	-	-	-	-	-	-	X	-
10	Skills in problem solving in Physics and related discipline	-	X	-	X	-	-	-	-	-
11	Develop Technical Communication skills	-	X	X	X	X	X	X	X	X
12	Developing analytical skills and popular communication	-	X	X	-	X	X	X	X	X
13	Developing ICT skills	-	X	-	-	-	-	-	-	-
14	Demonstrate Professional behaviour with respect to attribute like objectivity, ethical values, self reading, etc	X	X	X	X	X	X	X	X	X

Core Course & Generic Elective & Discipline Specific Electives for B.Sc Regular

S. No.		CC-I/ GEC-I	CC-II/ GEC-II	CC-III/ GEC-III	CC-IV/ GEC-IV	GEC-V	GEC-VI	GEC-VII	GEC-VIII	GEC-IX	GEC-X	GEC-XI	GEC/ DSEC-XII
1	Fundamental understanding of the field	X	X	X	X	X	X	X	X	X	X	X	X
2	Application of basic Physics concepts	X	X	X	X	X	X	X	X	X	X	X	X
3	Linkages with related disciplines	X	X	X	X	X	X	X	X	X	X	X	X
4	Procedural knowledge for professional subjects	X	X	X	X	X	X	X	X	X	X	X	X
5	Skills in related field of specialization	X	X	X	X	X	X	X	X	X	X	X	X
6	Ability to use in Physics problem	X	X	X	X	X	X	X	X	X	X	X	_
7	Skills in Mathematical modeling	X	X	X	X	_	X	X	X	_	_	_	_
8	Skills in performing analysis and interpretation of data	X	X	X	X	X	X	X	X	X	_	X	_
9	Develop investigative Skills	X	X	X	X	X	_	X	X	X	_	_	_
10	Skills in problem solving in Physics and related discipline	X	X	X	X	X	X	X	X	X	_	X	_
11	Develop Technical Communication skills	X	X	X	X	X	X	X	X	X	_	X	_
12	Developing analytical	X	X	X	X	_	X	X	X	X	X	X	X

	skills and popular communication												
13	Developing ICT skills	X	X	X	X	X	_	X	X	_	X	_	X
14	Demonstrate Professional behaviour with respect to attribute like objectivity, ethical values, self reading, etc	X	X	X	X	X	X	X	X	X	X	X	X

6. Structure of UG Courses in Physics

Distribution of different Courses in each semester with their credits for B.Sc (General) Physics with PCM, PMC & PEM

Semester	Compulsory Core Courses (CC) each with 06 credit (Total no. of Papers 12) 04 Core courses are compulsory to be selected from each subject A B and C	Discipline Specific Elective(DSE) Select any 02 courses form each subject A B and C	Ability Enhancement Compulsory Courses (AECC) Select any 02 from 03 courses	Skill Enhancement Course (SEC) Select any 08 courses choosing (at least 2 and not more than 3) form each subject A B and C	Total Credits
Sem I	CC-1A CC-1B CC-1C	-	AECC-1	-	22
Sem II	CC-2A CC-2B CC-2C	-	AECC-2	-	22
Sem III	CC-3A CC-3B CC-3C	-	-	SEC-1A SEC-2B	22
Sem IV	CC-4A CC-4B CC-4C	-	-	SEC-2A SEC-2C	22
Sem V	-	DSE-1A DSE -1B DSE -1C	-	SEC-2B SEC-2C	22
Sem VI	-	DSE -2A DSE -2B DSE -2C	-	Any 02 SEC courses from discipline A, B & C	22
Total Credits	72	36	8	16	132

Distribution of different Courses in each semester with their credits for B.Sc. (Hons) Physics

Semester	**Core Courses (CC) each with 06 credit All 14 courses are compulsory**	**Generic Elective(GE)**	**Skill Enhancement Course (SEC) Select any 4 out of 9 courses**	**Discipline Specific Elective (DSE) Select any four out of 16 courses**	**Ability Enhancement Compulsory Courses (AECC) Select any 2 out of 3 courses**	**Total Credit**
Sem I	CC-1 CC-2	GEC-1	SEC-1	-	AECC-1	24
Sem II	CC-3 CC-4	GEC-2	SEC-2	-	AECC-2	24
Sem III	CC-5 CC-6 CC-7	GEC-3	-	-	-	24
Sem IV	CC-8 CC-9 CC-10	GEC-4	-	-	-	24
Sem V	CC-11 CC-12	-	SEC-3	DSE-1 DSE-2	-	26
Sem VI	CC-13 CC-14	-	SEC-4	DSE-3 DSE-4	-	26
Total Credit	84	24	8	24	8	148

6.1 Structure of courses in B.Sc Physics, B.Sc (PCM), B.Sc (PEM), B.Sc (PMC)

The B.Sc. programs with Physics as one of the subjects consists of 132 credits based on the Choice Based Credit System (CBCS) approved by the UGC with 1 hour for each credit for theory/tutorials and 2 hours for each credit of laboratory work. Out of 132 credits, 108 credits are equally divided between Physics and two other subjects (36 credits each) based on the choice of the candidates while the additional 16 credits consist of Skilled Enhancement courses (SEC) and 8 credits of Ability Enhancement Compulsory Courses (AECC) equally divided (4 credits each) between disciplines of the Environmental sciences and Languages/communications. The 132 credit courses comprise of 72 credits of core courses (CC) and 8 credits of AECC which are mandatory as well as 36 credits of Discipline specific courses (DSE) and 16 credits of Skilled Enhancement courses (SEC) which are elective. A student can take more than 132 credits in total (but not more than 148 credits) to qualify for the grant of the B.Sc. Physics degree after completing them successfully as per rules and regulations of the HEI.

6.2 Structure of courses in B.Sc (Honours) Physics

The B.Sc. (Honours) Physics program is also based on the Choice Based Credit System (CBCS) approved by the UGC with a total of 148 credits. Out of 148 credits, 84 credits of core courses (CC) and 8 credits of Ability Enhancement Compulsory Courses (AECC) are mandatory while 24 credits of Discipline specific course and 24 credits of Generic Elective Courses (GEC) from Interdisciplinary disciplines as well as 16 credits of Skilled Enhancement courses are elective. A student can offer more than 148 credits (but not more than a total of 160 credits) to qualify for the grant of the B.Sc. (Honours) Physics degree after completing them successfully as per rules and regulations of the HEI.

A detailed list of Core Courses, Discipline Specific Courses (DSE) Generic Elective Courses (GEC), Skill Enhancement Courses (SEC) and Ability Enhancement Compulsory Courses (AECC) are given in Section 6.3

6.3 List of Physics Courses

6.3.1 Core Courses (CC)

All the courses have 6 credits with 4 credits of theory and 2 credits of practicals.

B.Sc Physics / B.Sc (PCM)	B.Sc (Honours) Physics	B.Sc (PEM)	B.Sc(PMC)
-	Mathematical Physics – I +Lab	-	-
	Mechanics + Lab		
Mechanics + Lab		Mechanics + Lab	Mechanics + Lab
	Electricity and Magnetism + Lab		
Electricity and Magnetism+ Lab		Electricity and Magnetism + Lab	Electricity and Magnetism + Lab
	Thermal Physics +Lab		
Thermal Physics and Statistical Mechanics + Lab		Thermal Physics and Statistical Mechanics + Lab	Thermal Physics and Statistical Mechanics + Lab
	Waves and Optics +Lab		
Waves and Optics + Lab		Waves and Optics + Lab	Waves and Optics + Lab
	Mathematical Physics – II + Lab		
-	Digital Systems and Applications + Lab	-	-
-	Mathematical Physics – III + Lab	-	-
-	Elements of Modern Physics + Lab	-	-
-	Analog Systems and Applications + Lab	-	-
-	Quantum Mechanics and Applications + Lab	-	-
-	Solid State Physics + Lab	-	-
-	Electromagnetic Theory + Lab	-	-
-	Statistical Mechanics + Lab	-	-

6.3.2 Discipline Specific Electives (DSE)

All the courses have 6 credits with 4 credits of theory and 2 credits of practicals or 5 credits of theory and 1 credit of Tutorials.

B.Sc Physics / B.Sc (PCM)	B.Sc (Honours) Physics	B.Sc (PEM)	B.Sc(PMC)
-	Experimental Techniques + Lab	-	-
	Embedded Systems – Introduction of Microcontroller+ Lab		
Embedded Systems –Introduction of Microcontroller + Lab		-	Embedded Systems – Introduction of Microcontroller + Lab
-	Physics of Devices and Communication + Lab	-	-
-	Advanced Mathematical Physics I +Lab	-	-
-	Advanced Mathematical Physics II + Tutorial	-	-
-	Classical Dynamics + Tutorial		-
-	Applied Dynamics + Lab	-	-
-	Communication System + Lab	-	-
Nuclear and Particle Physics + Tutorials	Nuclear and Particle Physics + Tutorials	Nuclear and Particle Physics + Tutorials	Nuclear and Particle Physics + Tutorials
-	Astronomy and Astrophysics + Tutorials	-	-
-	Atmospheric Physics + Lab	-	-
-	Nano Material and Applications + Lab		
-	Physics of the Earth +Tutorials	-	-
-	Digital Signal Processing +Lab	-	-
Medical Physics + Lab	Medical Physics + Lab	Medical Physics + Lab	Medical Physics + Lab
-	Biological Physics + Tutorials	-	-
Dissertation	Dissertation	Dissertation	Dissertation

Digital , Analog and Instrumentation + Lab	**-**	**-**	**Digital , Analog and Instrumenta-tion + Lab**
Elements of Modern Physics + Lab	**-**	**Elements of Modern Physics + Lab**	**Elements of Modern Physics + Lab**
Mathematical Physics + Lab	**-**	**Mathematical Physics + Lab**	**Mathematic-al Physics +Lab**
Solid State Physics +Lab	**-**	**Solid State Physics +Lab**	**Solid State Physics +Lab**
Quantum Mechanics + Lab	**-**	**Quantum Mechanics +Lab**	**Quantum Mechanics + Lab**

6.3.3 Skill Enhancement Courses (SEC)

All courses have 4 credits with 2 credits of theory and 2 credits of Practicals / Tutorials / Projects and Field Work to be decided by HEI.

B.Sc Physics / B.Sc (PCM)	**B.Sc (Honours) Physics**	**B.Sc (PEM)**	**B.Sc(PMC)**
Physics Workshop Skills	Physics Workshop Skills	Physics Workshop Skills	Physics Workshop Skills
Computational Physics Skills	Computational Physics Skills	Computational Physics Skills	Computational Physics Skills
Electrical Circuit and Network Skills	Electrical Circuit and Network Skills	Electrical Circuit and Network Skills	Electrical Circuit and Network Skills
Basic Instrumentation Skills	Basic Instrumentation Skills	Basic Instrumentation Skills	Basic Instrumentation Skills
Renewable Energy and Energy Harvesting	Renewable Energy and Energy Harvesting	Renewable Energy and Energy Harvesting	Renewable Energy and Energy Harvesting
Technical Drawing	Technical Drawing	Technical Drawing	Technical Drawing
Radiation Safety	Radiation Safety	Radiation Safety	Radiation Safety
Applied Optics	Applied Optics	Applied Optics	Applied Optics

6.3.4 Generic Electives (GE) (Minor Physics)

All the courses have 6 credits with 4 for other Departments/Disciplines credits of theory and 2 credits ofpracticals or 5 credits of theory and 1credit of Tutorials.

Generic Elective papers for other B.Sc (Honours) programs other than B.Sc (Honours) Physics
Mechanics + Lab
Electricity and Magnetism+ Lab
Thermal Physics and Statistical Mechanics + Lab
Waves and Optics + Lab
Embedded Systems –Introduction of Microcontroller + Lab
Nuclear and Particle Physics + Tutorials
Digital , Analog and Instrumentation + Lab
Elements of Modern Physics + Lab
Mathematical Physics + Lab
Solid State Physics +Lab
Quantum Mechanics + Lab

6.3.5 Ability Enhancement Compulsory Courses (AECC)

All the courses have 4 credits including Theory / Practicals / Projects

AECC	B.Sc Physics / B.Sc (PCM) / B.Sc (PEM) / B.Sc(PMC) /B.Sc (Honours) Physics
1	English
2	MIL Communications
3	Environment Science

6.4 Course Learning Outcomes (CLO)

A. B.Sc. (Hons.) Physics Courses

6.4.1. Core Courses (CC)

C-I: MATHEMATICAL PHYSICS-I
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Revise the knowledge of calculus, vectors, vector calculus, probability and probability distributions. These basic mathematical structures are essential in solving problems in various branches of Physics as well as in engineering.
- Learn the curvilinear coordinates which have applications in problems with spherical and cylindrical symmetries.
- Learn the Dirac delta function its properties, which have applications in various branches of Physics, especially quantum mechanics.
- In the laboratory course, learn the fundamentals of the C and C++ programming languages and their applications in solving simple physical problems involving interpolations, differentiations, integrations, differential equations as well as finding the roots of equations.

(ii) Broad contents of the course:

- Calculus
- Vector Calculus
- Orthogonal Curvilinear Coordinates
- Dirac Delta function and its properties
- Introductory theory of probability

(iii) Skills to be learned

- Training in calculus will prepare the student to solve various mathematical problems.
- He / she shall develop an understanding of how to formulate a physics problem and solve given mathematical equation risen out of it.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-II: MECHANICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

After going through the course, the student should be able to

- Understand laws of motion and their application to various dynamical situations, notion of inertial frames and concept of Galilean invariance. He / she will learn the concept of conservation of energy, momentum, angular momentum and apply them to basic problems.
- Understand the analogy between translational and rotational dynamics, and application of both motions simultaneously in analyzing rolling with slipping.
- Write the expression for the moment of inertia about the given axis of symmetry for different uniform mass distributions.
- Understand the phenomena of collisions and idea about center of mass and laboratory frames and their correlation.
- Understand the principles of elasticity through the study of Young Modulus and modulus of rigidity.
- Understand simple principles of fluid flow and the equations governing fluid dynamics.
- Apply Kepler's law to describe the motion of planets and satellite in circular orbit, through the study of law of Gravitation.
- Explain the phenomena of simple harmonic motion and the properties of systems executing such motions.
- Describe how fictitious forces arise in a non-inertial frame, e.g., why a person sitting in a merry-go-round experiences an outward pull.
- Describe special relativistic effects and their effects on the mass and energy of a moving object.
- appreciate the nuances of Special Theory of Relativity (STR)

- In the laboratory course, the student shall perform experiments related to mechanics (compound pendulum), rotational dynamics (Flywheel), elastic properties (Young Modulus and Modulus of Rigidity) and fluid dynamics (verification of Stokes law, Searle method) etc.

(ii) Broad contents of the course:

- Fundamental of Dynamics
- Work and Energy
- Collisions
- Rotational Dynamics
- Elasticity
- Fluid Motion
- Gravitation and cathode force Motion
- Oscillation
- Non-inertial Systems
- Special Theory of Relativity

(iii) Skills to be learned

- Learn basics of the kinematics and dynamics linear and rotational motion.
- Learn the concepts of elastic in constant of solids and viscosity of fluids.
- Develop skills to understand and solve the equations of Newtonian Gravity and central force problem.
- Acquire basic knowledge of oscillation.
- Learn about inertial and non-inertial systems and essentials of special theory of relativity.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-III: ELECTRCITY AND MAGNETISM
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

After going through the course, the student should be able to

- Demonstrate Gauss law, Coulomb's law for the electric field, and apply it to systems of point charges as well as line, surface, and volume distributions of charges.
- Explain and differentiate the vector (electric fields, Coulomb's law) and scalar (electric potential, electric potential energy) formalisms of electrostatics.
- Apply Gauss's law of electrostatics to solve a variety of problems.
- Articulate knowledge of electric current, resistance and capacitance in terms of electric field and electric potential.
- Demonstrate a working understanding of capacitors.
- Describe the magnetic field produced by magnetic dipoles and electric currents.
- Explain Faraday-Lenz and Maxwell laws to articulate the relationship between electric and magnetic fields.
- Understand the dielectric properties, magnetic properties of materials and the phenomena of electromagnetic induction.
- Describe how magnetism is produced and list examples where its effects are observed.
- Apply Kirchhoff's rules to analyze AC circuits consisting of parallel and/or series combinations of voltage sources and resistors and to describe the graphical relationship of resistance, capacitor and inductor.
- Apply various network theorems such as Superposition, Thevenin, Norton, Reciprocity, Maximum Power Transfer, etc. and their applications in electronics, electrical circuit analysis, and electrical machines.
- In the laboratory course the student will get an opportunity to verify various laws in electricity and magnetism such as Lenz's law, Faraday's law and learn about the construction, working of various measuring instruments.
- Should be able to verify of various circuit laws, network theorems elaborated above, using simple electric circuits.

(ii) Broad contents of the course

- Electric Field and Electric Potential
- Conservative nature of Electrostatic Field
- Electrostatic energy of system of charges
- Dielectric Properties of Matter
- Magnetic Field
- Magnetic Properties of Matter
- Electromagnetic Induction
- Electrical Circuits
- Network Theorems
- Ballistic Galvanometer

(iii) Skills to be learned

- This course will help in understanding basic concepts of electricity and magnetism and their applications.
- Basic course in electrostatics will equips the student with required prerequisites to understand electrodynamics phenomena.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-IV: WAVES AND OPTICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

This course will enable the student to

- Recognize and use a mathematical oscillator equation and wave equation, and derive these equations for certain systems.
- Apply basic knowledge of principles and theories about the behaviour of light and the physical environment to conduct experiments.
- Understand the principle of superposition of waves, so thus describe the formation of standing waves.
- Explain several phenomena we can observe in everyday life that can be explained as wave phenomena.
- Use the principles of wave motion and superposition to explain the Physics of polarisation, interference and diffraction.
- Understand the working of selected optical instruments like biprism, interferometer, diffraction grating, and holograms.
- In the laboratory course, student will gain hands-on experience of using various optical instruments and making finer measurements of wavelength of light using Newton Rings experiment, Fresnel Biprism etc. Resolving power of optical equipment can be learnt firsthand.
- The motion of coupled oscillators, study of Lissajous figures and behaviour of transverse, longitudinal waves can be learnt in this laboratory course.

(ii) Broad contents of the course

- Superposition of Two Collinear Harmonic Oscillations
- Superposition of Two Perpendicular Harmonic Oscillations
- Waves Motion – General
- Velocity of Waves
- Superposition of Two Harmonics Waves

- Wave Optics
- Interference
- Michelson's Interferometer
- Diffraction
- Fraunhofer Diffraction
- Fresnel Diffraction
- Holography

(iii) Skills to be learned

- He / she shall develop an understanding of various aspects of harmonic oscillations and waves specially.

  (i) Superposition of collinear and perpendicular harmonic oscillations
  (ii) Various types of mechanical waves and their superposition.

- This course in basics of optics will enable the student to understand various optical phenomena, principles, workings and applications optical instruments.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-V: MATHEMATICAL PHYSICS-II
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Learn the Fourier analysis of periodic functions and their applications in physical problems such as vibrating strings etc.
- Learn about the special functions, such as the Hermite polynomial, the Legendre polynomial, the Laguerre polynomial and Bessel functions and their differential equations and their applications in various physical problems such as in quantum mechanics which they will learn in future courses in detail.
- Learn the beta, gamma and the error functions and their applications in doing integrations.

- Know about the basic theory of errors, their analysis, estimation with examples of simple experiments in Physics.
- Acquire knowledge of methods to solve partial differential equations with the examples of important partial differential equations in Physics.
- In the laboratory course, learn the basics of the Scilab software, their utility, advantages and disadvantages.
- Apply the Scilab software in curve fittings, in solving system of linear equations, generating and plotting special functions such as Legendre polynomial and Bessel functions, solving first and second order ordinary and partial differential equations.

(ii) Broad contents of the course:

- Fourier Series
- Special Functions
- Special Integrals
- Theory of Errors
- Partial Differential Equation

(iii) Skills to be learned

- Training in mathematical tools like calculus, integration, series solution approach , special function will prepare the student to solve ODE, PDE's which model physical phenomena.
- He / she shall develop an understanding of how to model a given physical phenomena such as pendulum motion, rocket motion, stretched string, etc., into set of ODE's, PDE's and solve them.
- These skills will help in understanding the behavior of the modeled system/s.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-VI: THERMAL PHYSICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Comprehend the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations.
- Learn about Maxwell's thermodynamic relations.
- Learn the basic aspects of kinetic theory of gases, Maxwell-Boltzman distribution law, equitation of energies, mean free path of molecular collisions, viscosity, thermal conductivity, diffusion and Brownian motion.
- Learn about the real gas equations, Van der Waal equation of state, the Joule-Thompson effect.
- In the laboratory course, the students are expected to do some basic experiments in thermal Physics, viz., determinations of Stefan's constant, coefficient of thermal conductivity, temperature coefficient of resistant, variation of thermo-emf of a thermocouple with temperature difference at its two junctions and calibration of a thermocouple.

(ii) Broad contents of the course:

- Zeroth and First Law of Thermodynamics
- Second Law of Thermodynamics
- Entropy
- Thermodynamic Potentials
- Maxwell's Thermodynamic Relations
- Kinetic Theory of Gases :
  Distribution of Velocities
  Molecular Collisions
  Real Gases

(iii) Skills to be learned

- This basic course in thermodynamics will enable the student to understand various thermo dynamical concepts, principles.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-VII: DIGITAL SYSTEMS AND APPLICATIONS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

As the successful completion of the course the student is expected to be conversant with the following.

- Basic working of an oscilloscope including its different components and to employ the same to study different wave forms and to measure voltage, current, frequency and phase.
- Secure first-hand idea of different components including both active and passive components to gain a insight into circuits using discrete components and also to learn about integrated circuits.
- About analog systems and digital systems and their differences, fundamental logic gates, combinational as well as sequential and number systems.
- Synthesis of Boolean functions, simplification and construction of digital circuits by employing Boolean algebra.
- Sequential systems by choosing FlipFlop as a building bock- construct multivibrators, counters to provide a basic idea about memory including RAM,ROM and also about memory organization.
- Microprocessor and assembly language programming with special reference to IntelµP 8085.
- In the laboratory he is expected to construct both combinational circuits and sequential circuits by employing NAND as building blocks and demonstrate Adders, Subtractors, Shift Registers, and multivibrators using 555 ICs. He is also expected to use µP 8085 to demonstrate the same simple programme using assembly language and execute the programme using a µP kit.

(ii) Broad contents of the course:

- Digital storage oscilloscope.
- Active and passive filters
- Fundamental logic gates, combinational as well as sequential and number systems.
- Synthesis of Boolean functions, simplification and construction of digital circuits by employing Boolean algebra.
- Sequential systems by choosing Flip Flop as a building bock- construct multivibrators, counters to provide a basic idea about memory including RAM,ROM and also about memory organization.
- Microprocessor and assembly language programming with special reference to Intel μP 8085.

(iii) Skills to be learned

- Acquire skills to understanding the functioning and operation of CRO to measure physical quantities in electrical and electronic circuits.
- Learn the basics of IC and digital circuits, and difference between analog and digital circuits. Various logic GATES and their realization using diodes and transmitters.
- Learn fundamental of Bolean algebra and their role in constructing digital circuits.
- Learn about combinatorial and sequential systems by building block circuits to construct multivibrators and counters.
- Understand basics of microprocessor and assembly language programming with examples.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-VIII: MATHEMATICAL PHYSICS-III
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Learn about the complex numbers and their properties, functions of complex numbers and their properties such as analyticity, poles and residues. The students are expected to learn the residue theorem and its applications in evaluating definite integrals.
- Learn about the Fourier transform, the inverse Fourier transform, their properties and their applications in physical problems. They are also expected to learn the Laplace transform, the inverse Laplace transforms, their properties and their applications in solving physical problems.
- In the laboratory course, the students should apply their C++/Scilab programming language to solve the following problems:

(i) Solution first- and second- order ordinary differential equations with appropriate boundary conditions,

(ii) Evaluation of the Gaussian integrals,

(iii) Evaluation of a converging infinite series up to a desired accuracy,

(iv) Evaluation of the Fourier coefficients of a given periodic function,

(v) Plotting the Legendre polynomials and the Bessel functions of different orders and interpretations of the results,

(vi) Least square fit of a given data to a graph,

(ii) Broad contents of the course:

- Complex Analysis
- Integrals Transforms
- Fourier Transforms
- Laplace Transform

(iii) Skills to be learned

- Knowledge of various mathematical tools like complex analysis, integral transform will equip the student with reference to solve a given ODE, PDE.
- These skills will help in understanding the behavior of the modeled system/s.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-IX: ELEMENTS OF MODERN PHYSICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Know main aspects of the inadequacies of classical mechanics and understand historical development of quantum mechanics and ability to discuss and interpret experiments that reveal the dual nature of matter.
- Understand the theory of quantum measurements, wave packets and uncertainty principle.
- Understand the central concepts of quantum mechanics: wave functions, momentum and energy operator, the Schrodinger equation, time dependent and time independent cases, probability density and the normalization techniques, skill development on problem solving e.g. one dimensional rigid box, tunneling through potential barrier, step potential, rectangular barrier.
- Understanding the properties of nuclei like density, size, binding energy, nuclear forces and structure of atomic nucleus, liquid drop model and nuclear shell model and mass formula.
- Ability to calculate the decay rates and lifetime of radioactive decays like alpha, beta, gamma decay. Neutrinos and its properties and role in theory of beta decay.
- Understand fission and fusion well as nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.
- Understand various interactions of electromagnetic radiation with matter. Electron positron pair creation.
- Understand the spontaneous and stimulated emission of radiation, optical pumping and population inversion. Three level and four level lasers. Ruby laser and He-Ne laser in details. Basic lasing.
- In the laboratory course, the students will get opportunity to perform the following experiments
- Measurement of Planck's constant by more than one method.
- Verification of the photoelectric effect and determination of the work Function of a metal.

- Determination of the charge of electron and e/m of electron.
- Determination of the ionization potential of atoms.
- Determine the wavelength of the emission lines in the spectrum of Hydrogen atom.
- Determine the absorption lines in the rotational spectrum of molecules.
- Determine the wavelength of Laser sources by single and Double slit experiments
- Determine the wavelength and angular spread of He-Ne Laser using plane diffraction grating.
- Verification of the law of the Radioactive decay and determine the mean life time of a Radioactive Source, Study the absorption of the electrons from Beta decay. Study of the electron spectrum in Radioactive Beta decays of nuclei.
- Plan and Execute 2-3 group projects in the field of Atomic, Molecular and Nuclear Physics in collaboration with other institutions, if, possible where advanced facilities are available.

(ii) Broad contents of the course:

- One dimensional potential problem of bound states and scattering.
- Elementary introduction of nuclear physics with emphasis on

  (i) Nuclear Structure
  (ii) Nuclear Forces
  (iii) Nuclear Decays
  (iv) Fission and Fusion

- Introduction to Lasers.

(iii) Skills to be learned

- Comprehend the failure of classical physics and need for quantum physics.
- Grasp the basic foundation of various experiments establishing the quantum physics by doing the experiments in laboratory and interpreting them.
- Formulate the basic theoretical problems in one, two and three dimensional physics and solve them.

- Learning to apply the basic skills developed in quantum physics to various problems in

  (i) Nuclear Physics
  (ii) Atomic Physics
  (iii)Laser Physics

- Learn to apply basic quantum physics to Ruby Laser, He-Ne Laser

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-X: ANALOG SYSTEMS AND APPLICATIONS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

At the end of the course the student is expected to assimilate the following and possesses basic knowledge of the following.

- N- and P- type semiconductors, mobility, drift velocity, fabrication of P-N junctions; forward and reverse biased junctions.
- Application of PN junction for different type of rectifiers and voltage regulators.
- NPN and PNP transistors and basic configurations namely common base, common emitter and common collector, and also about current and voltage gain.
- Biasing and equivalent circuits, coupled amplifiers and feedback in amplifiers and oscillators.
- Operational amplifiers and knowledge about different configurations namely inverting and non-inverting and applications of operational amplifiers in D to A and A to D conversions.
- To characterize various devices namely PN junction diodes, LEDs, Zener diode, solar cells, PNP and NPN transistors. Also construct amplifiers and oscillators using discrete components. Demonstrate inverting and non-inverting amplifiers using op-amps.

(ii) Broad contents of the course

- N- and P- type semiconductors,
- Fabrication of p-n junctions; forward and reverse biased junctions.
- Application of P N junction
- Rectifiers and voltage regulators.
- NPN and PNP transistors and
- Common base, common emitter and common collector
- Current and voltage gain.
- Biasing and equivalent circuits,
- Coupled amplifiers and feedback in amplifiers and oscillators.

- Operational amplifiers and its applications in D to A and A to D convertors

(iii) Skills to be learned

- Learn basic concepts of semiconductor diodes and their applications to rectifiers.
- Learn about junction transistor and their applications.
- Learn about different types of amplifiers including operational amplifier.

  (Op-Amp) and their applications.
- Learn about sinusoidal oscillators of various types and A/D conversion.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-XI: QUANTUM MECHANICS AND APPLICATIONS
QUANTUM MECHANICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

This course will enable the student to get familiar with quantum mechanics formulation.

- After an exposition of inadequacies of classical mechanics in explaining microscopic phenomena, quantum theory formulation is introduced through Schrodinger equation.
- The interpretation of wave function of quantum particle and probabilistic nature of its location and subtler points of quantum phenomena are exposed to the student.
- Through understanding the behavior of quantum particle encountering a i) barrier, ii) potential, the student gets exposed to solving non-relativistic hydrogen atom, for its spectrum and eigenfunctions.
- Study of influence of electric and magnetic fields on atoms will help in understanding Stark effect and Zeeman Effect respectively.
- The experiments using Sci-lab will enable the student to appreciate nuances involved in the theory.
- This basic course will form a firm basis to understand quantum many body problems.
- In the laboratory course, with the exposure in computational programming in the computer lab, the student will be in a position to solve Schrodinger equation for ground state energy and wave functions of various simple quantum mechanical one-dimensional and three dimensional potentials.

(ii) Broad contents of the course:

- Time dependent Schrodinger equation
- Time independent Schrodinger equation
- General discussion of bound states in an arbitrary potential
- Quantum Theory of hydrogen-like atoms
- Atoms in Electric and Magnetic Fields
- Atoms in External Magnetic Fields

- Many electron atoms

(iii) Skills to be learned

- This course shall develop an understanding of how to model a given problem such as particle in a box, hydrogen atom, hydrogen atom in electric fields.
- Many electron atoms, L-S and J-J couplings.
- These skills will help in understanding the different Quantum Systems in atomic and nuclear physics.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-XII: SOLID STATE PHYSICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

At the end of the course the student is expected to learn and assimilate the following.

- A brief idea about crystalline and amorphous substances, about lattice, unit cell, miller indices, reciprocal lattice, concept of Brillouin zones and diffraction of X-rays by crystalline materials.
- Knowledge of lattice vibrations, phonons and in depth of knowledge of Einstein and Debye theory of specific heat of solids.
- At knowledge of different types of magnetism from diamagnetism to ferromagnetism and hysteresis loops and energy loss.
- Secured an understanding about the dielectric and ferroelectric properties of materials.
- Understanding above the band theory of solids and must be able to differentiate insulators, conductors and semiconductors.
- Understand the basic idea about superconductors and their classifications.
- To carry out experiments based on the theory that they have learned to measure the magnetic susceptibility, dielectric constant, trace hysteresis loop. They will also employ to four probe methods to measure electrical conductivity and the hall set up to determine the hall coefficient of a semiconductor.

(ii) Broad contents of the course:

- Crystalline and amorphous substances, lattice, unit cell, miller indices, reciprocal lattice. Brillouin zones and diffraction of X-rays by crystalline materials.
- Lattice vibrations and phonons
- Different types of magnetism
- Dielectric and ferroelectric materials.
- Band theory of solids
- Insulators, conductors and semiconductors.
- Superconductors and their classifications.

(iii) Skills to be learned

- Learn basics of crystal structure and physics of lattice dynamics
- Learn the physics of different types of material like magnetic materials, dielectric materials, metals and their properties.
- Understand the physics of insulators, semiconductor and conductors with special emphasis on the elementary band theory of semiconductors.
- Comprehend the basic theory of superconductors. Type I and II superconductors, their properties and physical concept of BCS theory.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-XIII: ELECTROMAGNETIC THEORY
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Achieve an understanding of the Maxwell's equations, role of displacement current, gauge transformations, scalar and vector potentials, Coulomb and Lorentz gauge, boundary conditions at the interface between different media.
- Apply Maxwell's equations to deduce wave equation, electromagnetic field energy, momentum and angular momentum density.
- Analyse the phenomena of wave propagation in the unbounded, bounded, vacuum, dielectric, guided and unguided media.
- Understand the laws of reflection and refraction and to calculate the reflection and transmission coefficients at plane interface in bounded media.
- Understand the linear, circular and elliptical polarisations of em waves. Production as well as detection of waves in laboratory.
- Understand propagation of em waves in anisotropic media, uni-axial and biaxial crystals phase retardation plates and their uses.
- Understand the concept of optical rotation, theories of optical rotation and their experimental rotation, calculation of angle rotation and specific rotation.
- Understand the features of planar optical wave guide and obtain the Electric field components, Eigen value equations, phase and group velocities in a dielectric wave guide.
- Understand the fundamentals of propagation of electromagnetic waves through optical fibres and calculate numerical apertures for step and graded indices and transmission losses.
- In the laboratory course, the student gets an opportunity to perform experiments Demonstrating principles of
- Interference, Refraction and diffraction of light using monochromatic sources of light. Demonstrate interference, Refraction and Diffraction using microwaves.
- Determine the refractive index of glass and liquid using total internal reflection of light.
- Verify the laws of Polarisation for plane polarised light.

- Determine Polarisation of light by Reflection and determine the polarization angle off or air-glass surface
- Determine the wavelength and velocity of Ultrasonic waves in liquids using diffraction.
- Study specific rotation of sugar using Polarimeter.
- Analyze experimentally the Elliptically Polarised light using Babinet's Compensator
- Study Experimentally the angle dependence of radiation for a simple dipole antenna
- Plan and Execute 2-3 group projects for designing new experiments based on the Syllabii.

(ii) Broad contents of the course:

- Review of Maxwell's equations
- EM wave propagation in unbounded media of various types
- EM wave propagation in bounded media separated by two types of media
- Polarization of electromagnetic waves
- Wave guides
- Optical fibres

(iii) Skills to be learned

- Comprehend the role of Maxwell's equation in unifying electricity and magnetism.
- Derive expression for

    (i) Energy density
    (ii) Momentum density
    (iii) Angular momentum density of the electromagnetic field

- Learn the implications of Gauge invariance in EM theory in solving the wave equations and develop the skills to actually solve the wave equation in various media like

    (i) Vacuum
    (ii) Dielectric medium
    (iii) Conducting medium

(iv) Dilute plasma

- Derive and understand associated with the properties, EM wave passing through the interface between two media like

  (i) Reflection
  (ii) Refraction
  (iii) Transmission
  (iv) EM waves

- Learn the basic physics associated with the polarization of electromagnetic waves by doing various experiments for:

  (i) Plane polarized light
  (ii) Circularly polarized light
  (iii) Circularly polarized light

- Learn the application of EM theory to

  (i) Wave guides of various types
  (ii) Optical fibers in theory and experiment

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

C-XIV: STATISTICAL MECHANICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Understand the concepts of microstate, macrostate, ensemble, phase space, thermodynamic probability and partition function.
- Understand the combinatoric studies of particles with their distinguishably or indistinguishably nature and conditions which lead to the three different distribution laws e.g. Maxwell-Boltzmann distribution, Bose-Einstein distribution and Fermi-Dirac distribution laws of particles and their derivation.
- Comprehend and articulate the connection as well as dichotomy between classical statistical mechanics and quantum statistical mechanics.
- Learn to apply the classical statistical mechanics to derive the law of equipartition of energy and specific heat.
- Understand the Gibbs paradox, equipartition of energy and concept of negative temperature in two level system.
- Learn to derive classical radiation laws of black body radiation. Wiens law, Rayleigh Jeans law, ultraviolet catastrophe. Saha ionization formula.
- Learn to calculate the macroscopic properties of degenerate photon gas using BE distribution law, understand Bose-Einstein condensation law and liquid Helium. Bose derivation of Plank's law
- Understand the concept of Fermi energy and Fermi level, calculate the macroscopic properties of completely and strongly degenerate Fermi gas, electronic contribution to specific heat of metals.
- Understand the application of F-D statistical distribution law to derive thermodynamic functions of a degenerate Fermi gas, electron gas in metals and their properties.
- Calculate electron degeneracy pressure and ability to understand the Chandrasekhar mass limit, stability of white dwarfs against gravitational collapse.
- In the laboratory course, the students gets an opportunity to verify Stefan's Law of radiation and determine Stefan's constant.

- Design and perform some experiments to determine Boltzmann' Constant.
- Use Computer simulations to study:

   i. Planck's Black Body radiation Law and compare with the Wien's Law and Raleigh - Jean's Law in appropriate temperature region.
   ii. Specific Heat of Solids by comparing, Dulong-Petit, Einstein's and Debye's Laws and study their temperature dependence

- Compare the following distributions as a function of temperature for various energies and the parameters of the distribution functions:

   i. Maxwell-Boltzmann distribution
   ii. Bose-Einstein distribution
   iii. Fermi-Dirac distribution

- Do 3-5 assignments given by the course instructor to apply the methods of Statistical mechanics to simple problems in Solid State Physics and Astrophysics
- Do the regular weekly assignments of at least 2-3 problems given by the course instructor.

(ii) Broad contents of the course:

- Classical Statistics
- Classical Theory of Radiation
- Quantum Theory of Radiation
- Bose-Einstein Statistics and its Applications
- Fermi-Dirac Statistics and its Applications.

(iii) Skills to be learned

- Learn the basic concepts and definition of physical quantities in classical statistics and classical distribution law.
- Learn the application of classical statistics to theory of radiation.
- Comprehend the failure of classical statistics and need for quantum statistics.

- Learn the application of quantum statistics to derive and understand.

  1. Bose Einstein statistics and its applications to radiation.
  2. Ferm-Dirac statistic and its applications to quantum systems.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

6.4.2. Discipline Specific Elective Course (DSE)

DSE-I: EXPERIMENTAL TECHNIQUES
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

At the end of the course the student should be conversant with the following.

- About accuracy and precision, different types of errors and statistical analysis of data.
- About Noise and signal, signal to noise ratio, different types of noises and their identification.
- Concept of electromagnetic interference and necessity of grounding.
- About transducers and basic concepts of instrumentation-Different types of transducers and sensors.
- Working of a digital multimeter.
- Vacuum systems including ultrahigh vacuum systems.
- Conduct Experiments using different transducers including LVDT and gain hands on experience and verify the theory.

(ii) Broad contents of the course:

- Accuracy and precision,
- Different types of errors and statistical analysis of data.
- Noise and signal, signal to noise ratio, different types of noises
- Electromagnetic interference and necessity of grounding.
- Transducers
- Different types of transducers and sensors.
- Digital multimeter.
- Vacuum systems including ultrahigh vacuum systems.

(iii) Skills to be learned

- Develop skills to analyse data, make approximation and perform error analysis using basic methods of statistics.
- Learn the working principle of transduces, their application and study of the efficiency.

- Develop understanding of analog and digital instruments and earn to use them in making physical measurements.
- Develop their understanding of signal, noise, and fluctuations in making physical measurements.
- Understanding of Impedances Bridges, Q meters as well as vacuum systems using various types of pumps and pressure gauges.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-II: EMBEDDED SYSTEM: INTRODUCTION TO MICROCONTROLLERS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

At the successful completion of the course the student is expected to master the following.

- Embedded systems including its generic architecture, design and classifications, Embedded processors and microcontrollers.
- Organization of intel microprocessor 8085, its architecture, pin diagram, timing diagram, instruction set and programming in assembly language.
- Organization of Intel 8051 microcontroller, its architecture, instruction set, programming and its memory organization, timing diagram.
- Input/output operations and manipulation for arithmetic and logical operations.
- Programming with and without interrupt service request.
- Interfacing parallel and serial ADC and DAC.
- Basics of embedded system development and product development with a brief introduction to Arduino.
- Student shall be able to design, fabricate, test and run the programs.

(ii) Broad contents of the course:

- Embedded Systems
- Intel microprocessor 8085.
- Intel 8051 microcontroller, architecture, instruction set, programming and its memory organization, timing diagram.
- Input/output operations and manipulation for arithmetic and logical operations.
- Programming with and without interrupt service request.
- Interfacing parallel and serial ADC and DAC.
- Embedded system development and product development

(iii) Skills to be learned

- Learn the architecture of embedded systems, their classification and application.
- Learn about the microprocessors and the organization of microprocessor based systems.
- Acquire knowledge of microcontrollers and their role in 1/0 port programming and their interface with peripherals.
- Learn about analog to digital and digital to analog convertors.
- Learn basics of Arduino and programming.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-III: PHYSICS OF DEVICES AND COMMUNCICATION
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

At the successful completion of the course the student is expected to master the following.

- Metal oxide semiconductors, UJT, JFET, MOSFET, Charge coupled Devices and Tunnel Diode.
- Power Supply and the role of Capacitance and Inductance filters.
- Active and passive filters and various types of filters.
- Multivibrators using transistors, Phase locked loops, voltage controlled oscillators
- Basics of photolithography for IC fabrication, about masks and etching.
- Concepts of parallel and serial communication and knowledge of USB standards and GPIB.
- Basic idea of communication including different modulation techniques.

(ii) Broad contents of the course:

- Metal oxide semiconductors, UJT, JFET, MOSFET, Charge coupled Devices and Tunnel Diode.
- Power Supply and the role of Capacitance and Inductance filters.
- Active and passive filters and various types of filters.
- Multivibrators using transistors, Phase locked loops, voltage controlled oscillators
- Photolithography for IC fabrication, about masks and etching.
- Parallel and serial communications and USB standards and GPIB.
- Different modulation techniques.

(iii) Skills to be learned

- Acquire knowledge and skills to understand the ….. of the following devices and instruments and practical knowledge to use them by doing experiments in laboratory.

(i) UJT
(ii) BJT
(iii) MOSFET
(iv) CCD
(v) Tunnel Diodes
(vi) Various types of Power Supplies
(vii) Various types of Filters
(viii) Multivibrators
(ix) Oscillators

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-IV: ADVANCED MATHEMATICAL PHYSICS-I
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Learn the basic properties of the linear vector space such as linear dependence and independence of vectors, change of basis, isomorphism and homomorphism, linear transformations and their representation by matrices.
- Learn the basic properties of matrices, different types of matrices viz., Hermitian, skew Hermitian, orthogonal and unitary matrices and their correspondence to physical quantities, e.g, operators in quantum mechanics. They should also learn how to find the eigenvalues and eigenvectors of matrices.
- Learn some basic properties tensors, their symmetric and antisymmetric nature, the Cartesian tensors, the general tensors, contravariant, covariant and mixed tensors and their transformation properties under coordinate transformations, physical examples of tensors such as moment of inertia tensor, energy momentum tensor, stress tensor, strain tensor etc.
- In the laboratory course, the students are expected to solve the following problems using the Scilab/C++ computer language:

  (i) Multiplication of two 3×3 matrices,
  (ii) Diagonalization of a matrix,
  (iii) Inverse of a matrix,
  (iv) Solutions of differential equations satisfied by different orthogonal polynomials and special function,
  (v) Determination of wave functions for stationary states as eigenfunctions of Hermitian differential operators and also the energy eigenvalues,

(ii) Broad contents of the course:

- Linear Vector Spaces
- Matrices
- Cartesian Tensors

- General Tensors

(iii) Skills to be learned

- In this course, the students should the learn the skills of doing calculations with the linear vector space, matrices, their eigenvalues and eigenvectors, tensors, real and complex fields, linear and multilinear transformations in various physical situations, e.g., the Lorentz transformations etc.
- They also become efficient in doing calculations with the 'calculus of variation'.
- In the laboratory course, the students should acquire the skills of applying the the C++/ SCILAB/MATLAB/MATHEMATICA software in solving standard physical problems.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-V: ADVANCED MATHEMATICAL PHYSICS-II
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

After the successful completion of the course, the students shall be able to

- Understand variational principle and apply it to calculate:

  (i) Geodesics in two and three dimensions

  (ii) Euler Lagrange Equation and apply it simple problems in one and two dimensions.

- Acquire basic concept of Hamiltonian, Hamilton's principle and Hamiltonian equation of motion, Poisson and Lagrange brackets.
- Learn elementary group theory, i.e., definition and properties of groups, subgroups, Homomorphism, isomorphism, normal and conjugate groups, representation of groups, Reducible and Irreducible groups. Examples and exercises.
- Learn the theory of probability, Random varialbles and probability distributions, Expectation values and variance. Various examples of probability distributions used in physics. The principle of least squares.

(ii) Broad contents of the course:

- Calculus of variationsand application to physical problems.
- Lagrangian and Hamiltonian equations of motion. Canonical variables. Legendre transformation, Poisson and Lagrange brackets and their properties.
- Elements of Group Theory.
- Theory of Probability and Probability Distributions.

(iii) Skills to be learned

- Ability to learn variational principle and do simple application to calculate geodesics in one, two and three dimensions.
- Ability to derive Euler equations of motion and apply it to simple pendulum and harmonic oscillator.

- Learn basics of group theory
- Learn the basics of the theory of probability and ability to calculate probability in simple problems.
- Derive various probability distributions and their application to different types of physical problems.
- Learn the principle of least squares and apply it tosome cases of analyzing physical experiments.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-VI: CLASSICAL DYNAMICS
(Credits: 06, Theory-05, Tutorials -01)

(i) Course learning outcome:

- Revise the knowledge of the Newtonian, the Lagrangian and the Hamiltonian formulations of classical mechanics and their applications in appropriate physical problems.
- Learn about the small oscillation problems.
- Recapitulate and learn the special theory of relativity- postulates of the special theory of relativity, Lorentz transformations on space-time and other four vectors, four-vector notations, space-time invariant length, length contraction, time dilation, mass-energy relation, Doppler effect, light cone and its significance, problems involving energy-momentum conservations.
- Learn the basics of fluid dynamics, streamline and turbulent flow, Reynolds's number, coefficient of viscosity and Poiseuille's equation.
- Review the retarded potentials, potentials due to a moving charge, Lienard Wiechert potentials, electric and magnetic fields due to a moving charge, power radiated, Larmor's formula and its relativistic generalization.

(ii) Broad contents of the course:

- Classical mechanics of point particles.
- Lagrangian and Hamiltonians of simple systems and derivations of equation of motion.
- Small amplitude oscillations
- Special theory of relativity
- Relativistic kinematics of one and two particle system.
- Basics of fluid dynamics

(iii) Skills to be learned

- Learn to define generalised coordinates, generalised velocities, generalised force and write Lagrangian for mechanical system in terms of generalised coordinates.

- Learn to derive Euler-Lagrange equation of motion and solve them for simple mechanical systems.
- Learn to write Hamiltonian for mechanical systems and derive and solve Hamilton's equation of motion for simple mechanical systems.
- Formulate the problem of small amplitude oscillation and solve them to obtain normal modes of oscillation and their frequencies in simple mechanical systems.
- Develop the basic concepts of special theory of relativity and its applications to dynamical systems of particles.
- Develop the methods of relativistic kinematics of one and two particle system and its application to two particle decay and scattering.
- Develop and understand the basic concepts of fluid dynamics and its applications to simple problems in liquid flow.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-VII: APPLIED DYNAMICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Understand the idea of dynamical systems, phase space and trajectories in phase space. Simple examples from mechanical systems.
- Comprehend illustrated examples of dynamical systems from other disciplines like chemistry, biology and economics and apply to do the qualitative analysis of some simple examples.
- Learn to use software packages to generate and visualize various trajectories.
- Understand chaos and their sensitive dependence on initial conditions with examples from 2d- Billiards problem and other physical systems like electron motion in mesoscopic conductors etc. Understand fractals as self-similar structures by giving examples from Nature and develop mathematical models for simple fractal structures.
- Understand various forms of dynamics and different routes to chaos.
- Ability to define, characterize and detect various types of chaos and their dependence on initial condition using various order parameters.
- Understand basic Physics of fluids and its dynamics theoretically and experimentally and by computational simulations.
- Understand basic properties of fluids I.e. viscosity, thermal conductivity, mass diffusivity, equation of state.
- Understand the Physics of different types of fluid flow phenomena as well as fluid flow visualizations like streamlines, pathlines and streakline flows.
- The students should be able to do Simulation /Computer experiments/Lab experiments in the following topics:

- Determination of the coupling Coefficients of Coupled pendulums and other coupled Oscillators
- Determination of the couplings and damping coefficient of the Damped Coupled Oscillators

- Simulation of Simple Population Models, Experimental growth and Decay, Logistic growth, Species Competition, Predator-Prey Dynamics, Simple genetic circuits
- Solve rate equations numerically for some simple chemical reactions
- Simulation of Trajectories in some problems like Sinai Billiard, and Electron Motion in Mesoscopic conductors
- Simulation of Fractal Formation in Deterministic Fractals, Self Similar Fractals and Fractals in nature like Trees, Coastlines and Earthquakes
- Simulation of some Fluid Flow Models like Streamlines, Pathlines, and Streakline flows

(ii) Broad contents of the course:

- Introduction to dynamical systems in various branches of physics
- Introduction to chaos and fractals with examples.
- Elements of fluid dynamics.

(iii) Skills to be learned

- Develop the concept of phase space to define and formulate the dynamical systems.
- Identify the dynamical systems in Biology, Chemistry, Economics and computing and visualizing trajectories using computer software.
- Learn computer software skills to do qualitative analysis of dynamical systems.
- Learn to generate computer simulation of trajectories in phase space for simple systems demonstrating chaotic systems.
- Learn to use fractal dimensions to describe self similar structures with help of examples.
- Learn to simulate onset of chaos in simple dynamical systems in various conditions.
- Formulate the basic equations of computational fluid dynamics using elementary theory of fluid dynamics.
- Learn to solve the basic equations to explain the basic properties of fluids like thermal conductivity, viscosity, mass diffusivity etc.
- Demonstrate some simple examples of fluid flow as described in the syllabi.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-VIII: COMMUNICATION ELECTRONICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

At the end of the course the student is expected to have an idea/concept of the following,

- Electromagnetic spectra and different frequency bands.
- Modulation, different types of modulation and about super heterodyne receivers.
- Concept of sampling, sampling theorem and multiplexing.
- Digital transmission, encoding and decoding.
- Satellite communication including uplinking and downlinking.
- Mobile communication/telephony and concepts of cell telephony.
- 2G, 3G, 4G and 5G (Quantitative).
- Apply the theory that they have learned in the theory class to gain hands on experience in building modulation and demodulation circuits; Transmitters and Receivers for AM and FM. Also to construct TDM, PAM, PWM, PPM and ASK, PSK and FSK modulator and verify their results.

(ii) Broad contents of the course:

- Electromagnetic spectra and different frequency bands.
- Modulation, different types of modulation and super heterodyne receivers.
- Sampling, sampling theorem and multiplexing.
- Digital transmission, encoding and decoding.
- Satellite communication
- Mobile communication/telephony and concepts of cell telephony.
- 2G, 3G, 4G and 5G (Quantitative).

(iii) Skills to be learned

- Learn the skills to understand the basic concepts of communication.
- Learn the techniques of different types of modulation of electromagnetic signals like

(i) Amplitude Modulation
(ii) Frequency Modulation
(iii) Phase Modulation
(iv) Analog Pulse Modulation
(v) Digital Pulse Modulation

- Learn basics of satellite communication.
- Learn concepts and application of mobile telephony system.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-IX: NUCLEAR & PARTICLE PHYSICS
(Credits: 06, Theory-05, Tutorials-01)

(i) Course learning outcome:

- Learn the ground state properties of a nucleus – the constituents and their properties, mass number and atomic number, relation between the mass number and the radius and the mass number, average density, range of force, saturation property, stability curve, the concepts of packing fraction and binding energy, binding energy per nucleon vs. mass number graph, explanation of fusion and fission from the nature of the binding energy graph.
- Know about the nuclear models and their roles in explaining the ground state properties of the nucleus –(i) the liquid drop model, its justification so far as the nuclear properties are concerned, the semi-empirical mass formula, (ii) the shell model, evidence of shell structure, magic numbers, predictions of ground state spin and parity, theoretical deduction of the shell structure, consistency of the shell structure with the Pauli exclusion principles.
- Learn about the process of radioactivity, the radioactive decay law, the emission of alpha, beta and gamma rays, the properties of the constituents of these rays and the mechanisms of the emissions of these rays, outlines of Gamow's theory of alpha decay and Pauli's theory of beta decay with the neutrino hypothesis, the electron capture, the fine structure of alpha particle spectrum, the Geiger-Nuttall law, the radioactive series.
- Learn the basic aspects of nuclear reactions, the Q-value of such reaction and its derivation from conservation laws, The reaction cross-sections, the types of nuclear reactions, direct and compound nuclear reactions, Rutherford scattering by Coulomb potential.
- Learn some basic aspects of interaction of nuclear radiation with matter- interaction of gamma ray by photoelectric effect, Compton scattering and pair production, energy loss due to ionization, Cerenkov radiation.
- Learn about the detectors of nuclear radiations- the Geiger-Mueller counter, the scintillation counter, the photo-multiplier tube, the solid state and semiconductor detectors.

- The students are expected to learn about the principles and basic constructions of particle accelerators such as the Van-de-Graff generator, cyclotron, betatron and synchrotron. They should know about the accelerator facilities in India.
- Gain knowledge on the basic aspects of particle Physics – the fundamental interactions, elementary and composite particles, the classifications of particles: leptons, hadrons (baryons and mesons), quarks, gauge bosons. The students should know about the quantum numbers of particles: energy, linear momentum, angular momentum, isospin, electric charge, colour charge, strangeness, lepton numbers, baryon number and the conservation laws associated with them.

(ii) Broad contents of the course:

- General properties of nuclei
- Nuclear models
- Radioactive decays
- Nuclear reactions
- Interaction of nuclear radiation with matter
- Detectors for nuclear interaction
- Particle accelerators
- Elementary particles and their properties

(iii) Skills to be learned

- Skills to describe and explain the properties of nuclei and derive them from various models of nuclear structure.
- To understand, explain and derive the various theoretical formulation of nuclear disintegration like α decay, β decay and σ decays.
- Develop basic understanding of nuclear reactions and decays with help of theoretical formulate and laboratory experiments.
- Skills to develop basic understanding of the interaction of various nuclear radiation with matter in low and high energy …….

- Ability to understand, construct and operate simple detector systems for nuclear radiation and training to work with various types of nuclear accelerators.
- Develop basic knowledge of elementary particles as fundamental constituent of matter, their properties, conservation laws during their interactions with matter.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-X: ASTRONOMY AND ASTROPHYSICS
(Credits: 06, Theory-05, Tutorials-01)

(i) Course learning outcome:

- Ability to comprehend astronomical scales and understand basic concepts of positional astronomy like astronomical coordinate system and measurement of distances, time and temperature and radius of star.
- Understand basic parameters of stars like brightness, radiant flux, luminosity, magnitude, orbits, spectral classification. H-R diagram
- Understand astronomical techniques, various types of optical telescopes and telescope mountings. Various types of detectors and their use with telescopes.
- Understanding Physics of sun and solar system: photosphere, chromosphere, corona, solar activity. Solar MHD, helioseismology, solar system and its origin. Nebular model. Tidal forces and planetary rings.
- Understanding Physics of stars and sun. Role of gravitation in astroPhysics, Newton vs Einstein, viral theorem and thermodynamic equilibrium. Atomic spectra, stellar spectra. Spectral classification, luminosity classification, temperature dependence.
- Acquire basic knowledge of galaxies and Milky Way. Morphology and classification of galaxies, intrinsic stages of galaxies, galactic halo, milky way, gas and dust in galaxy, spiral arm, rotation of galaxy and dark matter. Star clusters in Milky Way, galactic nucleus and its properties.
- Learn about the large scale structure and expanding universe cosmic distance ladder, distance measurements, cluster of galaxies, Hubble's law.

(ii) Broad contents of the course:

- Astronomical scalar and concepts of positional astronomy.
- Astronomical techniques for making measurements.
- Basics of solar and stellar physics.
- Milky Way and Galaxies – introductory knowledge.
- Large scale structures and expending universe.

(iii) Skills to be learned

- Skills to learn and operate astronomical instruments to perform observations related to the positional astronomy measurement.
- Conceptualize skills to understand basic parameters for describing the properties of stars and making experimental measurements, their interpretation and role in understanding of astrophysical phenomenon. Study of solar and stellar spectra.
- Learn to describe solar parameters, solar atmosphere, origin of solar system, solar and extra-solar planets, planetary rings.
- Acquire basic knowledge of Milky Way and Galaxies, their properties and structure.
- Skills for understanding basics of large scale structures and expending universe.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-XI: ATMOSPHERIC PHYSICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Good knowledge of Earth's atmosphere, its composition, effective temperature, Greenhouse effect. Hydrostatic equation and atmospheric thermodynamics. Local winds, clouds, fog, monsoon, cyclones, sea breeze and land breeze and thunderstorms etc.
- Essential knowledge of the instruments of meteorological observation, meteorological processes and systems.
- Understanding atmospheric dynamics, fundamental forces, conservation laws, rotating coordinate system and equations of motion. Circulation, vorticity, various types of circulations, atmospheric oscillations: biannual, annual and semi-annual oscillations.
- Understanding atmospheric waves. Surface water waves, accoustic waves, buoyancy waves, atmospheric gravity waves (AGW) and its propagation in non-homogeneous medium, Lamb and Rossy waves and their propagation in 3-dimension. Wave absorption and non linear effects.
- Skills to use atmospheric Radar and Lidar to study atmospheric phenomenon, basic knowledge of Radars and Lidars including Radar equation and signal processing. Develop numerical skills to do data analysis from Radar and Lidar.
- Knowledge of the classification and properties of aerosols, their concentrations and size distribution. Production and removal of aerosols. Radiative and health effects and observation techniques for aerosols.
- Understanding the absorption and scattering of solar radiation, Rayleigh scattering and Mie scattering, Boyer-Lambert law, optical phenomenon in atmosphere. Basics of radiometry.
- Through computer simulations in the laboratory course student will learn
- Atmospheric wave using Dispersion relations
- Kelvin waves, Rossby waves and Mountain waves
- Offline and if possible online processing of RADAR data

i. VHF RADAR
ii. X-band RADAR
iii. UHF RADAR

- Offline and Online processing of LIDAR data
- Study of Radiosonde data and its interpretation in terms of the atmospheric parameters
- Interpretation of the satellite data using radio Occultation technique
- Time Series Analysis of Temperature using long term data and implications for climate change
- Take up 2-3 projects in collaboration with nearest center of IMD , if available, for simple analysis and interpretation of local atmospheric data.

(ii) Broad contents of the course:

- General features of Earth's atmosphere.
- Atmospheric dynamics
- Atmospheric waves
- Atmospheric Radar and Lidar
- Atmospheric Aerosols.

(iii) Skills to be learned

- Develop skills to describe, understand and make measurements of various parameters to describe the physics of earth's atmosphere.
- Learn skills to formulate, solve the theoretical equations describing the atmospheric dynamics and develop software to simulate and demonstrate in laboratory the various atmospheric phenomenon like.
- Atmospheric oscillations of various types.
- Atmospheric waves of various types.
- Learn the physics and equations for signal processing with help of

(i) Radar
(ii) Lidar

and performing data analysis to understand atmospheric phenomenon.

- Learn to make various types of theoretical and experimental analyses to explore the atmospheric aerosols and the effect of solar and cosmic radiation on aerosols.
- Develop a theoretical and experimental understanding of the absorption and scattering of solar radiation with matter.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-XII: NANO MATERIALS AND APPLICATIONS
(Credits: 06, Theory-04, Practical-02)

(i) Course learning outcome:

At the end of the course the student is expected to possess the concept the following.

- In the Nano systems and its implications in modifying the properties of materials at the nanoscale.
- Concept of Quantum confinement, 3D,2D,1D and 0D nanostructure with examples.
- Different synthesis techniques including top down and bottom up approaches.
- Characterization of nanostructured materials using X-ray diffraction, electron microscopy, Atomic Force Microscopy and Scanning Tunneling Microscopy.
- Optical properties of nanostructured materials, modification of band gap, excitonic confinement.
- Applications of nanostructured materials in making devices namely MEMS, NEMS and other heterostructures for solar cell and LEDs.
- The student will synthesize nanoparticles by different chemical routs and characterize them in the laboratory using the different techniques he has learnt in the theory. He will also carry out thin film preparation and prepare capacitors and evaluate its performance. He also expected to fabricate a PN diode and study its I-V characteristics.

(ii) Broad contents of the course:

- Nanoscale Systems
- Synthesis of Nanostructure Materials
- Characterization
- Optical Properties
- Electron Transport
- Applications

(iii) Skills to be learned

- Develop basic understanding of nanostructured materials.

- Learn the synthesis and characterization of nanostructured materials.
- Understanding the optical properties of nanostructured materials and electron transport phenomenon.
- Lean to understand the functioning of various analytical techniques using

  (i) X-ray Diffraction
  (ii) Atomic Force Microscopy
  (iii) Scanning Electron Microscopy
  (iv) Scanning Tunneling Microscopy
  (v) Transmission Electron Microscopy

- Application of nanoparticles in various fields like:

  (i) LED
  (ii) Solar Cells
  (iii) Single Electron Transform Devices
  (iv) Magnetic Data Storage
  (v) Micro-electrochemical Systems (MEMS)
  (vi) Nano- electrochemical Systems (NEMS)

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-XIII: PHYSICS OF EARTH
(Credits: 06, Theory -05, Tutorial -01)

(i) Course learning outcome:

This course will provide an exposure to student

- In the origin of Universe, place of Earth as a third rock revolving around Sun, its satellite Moon and in general evolution of present day Universe.
- overview of the structure and evolution of the Earth as a dynamic planet within our solar system
- Application of physical principles of elasticity and elastic wave propagation to understand modern global seismology as a probe of the Earth's internal structure. The origin of magnetic field, Geodynamics of earthquakes and the description of seismic sources; a simple but fundamental theory of thermal convection; the distinctive rheological behaviour of the upper mantle and its top layer shall be understood.
- Climate and various roles played by water cycle, carbon cycle, nitrogen cycles in maintain steady state of earth shall be explored.
- This will enable the student to understand the contemporary dilemmas (climate change, bio diversity loss, population growth, etc.) disturbing the Earth
- In the tutorial section, through literature survey on the various aspects of health of Earth, project work / seminar presentation, he she will be to appreciate need to 'save' Earth.

(ii) Broad contents of the course:

- The Earth and the Universe
- Structure
- Dynamical Processes
- Evolution
- Disturbing the Earth – Contemporary dilemmas

(iii) Skills to be learned

Knowledge of the place of Earth in this Universe and its formation, structure and its evolution shall enable the student to appreciate the reasons for keeping Earth 'SAFE'

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-XIV: DIGITAL SIGNAL PROCESSING
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

At the end of the course the student is expected to have an idea/concept of the following,

- Fundamental classification of signals and systems based on the parameters which define them.
- Concept of Discrete-Time Fourier Transform and Z-transform on signals and its properties.
- Concept of Discrete Fourier Transform, different convolution techniques, filters and their classifications.
- Fluency in using Fast Fourier Transform.
- Understanding of Digital Filters and their classifications based on the response, design and algorithm.
- Signal generation, realization of systems and finding their transfer function, characterization using pole-zero plots and designing digital filters using Scilab simulations.

(ii) Broad contents of the course:

- Signals and systems based on the parameters
- Discrete-Time Fourier Transform and Z-transform on signals
- Convolution techniques, filters and their classifications.
- Fast Fourier Transforms.
- Digital Filters and their classifications based on the response, design and algorithm.

(iii) Skills to be learned

- Acquire basic understanding of Discrete-Time signals and systems.
- Learn the techniques of various types of fourier transforms …. in signal processing, i.e.,

(i) Discrete-Time Fourier Transforms

(ii) Discrete Fourier Transforms

(iii) Fast Fourier Transforms

- Learn various aspects of digital filters like

(i) Various types of Digital Filters

(ii) Realization of Digital Filters

(iii) Finite Impulse Response Digital Filters

(iv) Infinite Impulse Response Digital Filters

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-XV: MEDICAL PHYSICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

This course will enable the student to

- Focus on the application of Physics to clinical medicine.
- Gain a broad and fundamental understanding of Physics while developing particular expertise in medical applications.
- Learn about the human body, its anatomy, physiology and bioPhysics, exploring its performance as a physical machine. Other topics include the Physics of the senses.
- He / She will study diagnostic and therapeutic applications like the ECG, radiation Physics, X-ray technology, ultrasound and magnetic resonance imaging.
- Gain knowledge with reference to working of various diagnostic tools , medical imaging techniques, how ionizing radiation interacts with matter, how it affects living organisms and how it is used as a therapeutic technique and radiation safety practices
- Imparts functional knowledge regarding need for radiological protection and the sources of an approximate level of radiation exposure for treatment purposes.
- In the laboratory course, the student will be exposed to the workings of various medical devices. He / she gets familiarized with various detectors used in medical imaging, medical diagnostics. The hands-on experience will be very useful for the students when he / she enter the job market.

(ii) Broad contents of the course:

- Physics of the Body-I
- Physics of the Body –II
- Physics of Diagnostic and Therapeutic Systems-I
- Radiation Physics
- Medical Imaging Physics

- Radiation Oncology Physics
- Radiation and Radiation Protection
- Physics of Diagnostic and Therapeutic Systems-II

(iii) Skills to be learned

Essential physics of Medical Imaging, Radiological Physics, Therapeutic Systems and Radiation Therapy is acquired.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSE-XVI: BIOLOGICAL PHYSICS
(Credits: 06, Theory-05, Tutorials-01)

(i) Course learning outcome:

This course will enable student to

- Acquire mastery of the fundamental principles and applications of various branches of Physics in understanding biological systems.
- Nuggets of thermodynamics and statistical mechanics, electricity and magnetism, will help in understating heat transfer in biomaterials.
- Relevance of chemistry principles and thermodynamics in understanding energy transfer mechanism and protein folding in biological systems.
- He /she will acquire necessary mathematical skills in differential equations, analysis, and linear algebra for simulation studies.
- A basic course in bioPhysics will provide proficiency in basic lab skills, including understanding and using modern instrumentation and computers.
- Get exposure to complexity of life at i) the level of Cell, ii) level of multi cellular organism and iii) at macroscopic system – ecosystem and biosphere
- Student gets exposure to models of evolution.

(ii) Broad contents of the course:

- Overview
- Molecules of Life
- The complexity of Life
- Evolution

(iii) Skills to be learned

- Basic concepts about biological physics and evolution are learned.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

6.4.3. Skill-based Elective Courses (SEC)

SEC-I: PHYSICS WORKSHOP SKILLS
(Credits: 02)

(i) Course learning outcome:

- After the successful completion of the course the student is expected to acquire skills/ hands on experience / working knowledge on various machine tools, lathes, shapers, drilling machines, cutting tools, welding sets and also in different gear systems, pulleys etc. He /she will also acquire skills in the usage of multimeters, soldering iron, oscilloscopes, power supplies and relays.

(ii) Broad contents of the course:

- Introduction to make simple length, height, time, area, volume measurements.
- Mechanical skills needed to the workshop practice.
- Electrical and electronics skills related to the measurement of various electrical and electronics quantities.
- Introduction to Prime Movers.

(iii) Skills to be learned

- Learn to use mechanical tools to make simple measurement of length, height, time, area and volume.
- Obtain hand on experience of workshop practice by doing casting, foundry, machining, welding and learn to use various machine tool like lathe shaper, milling and drilling machines etc. and working with wooden and metal blocks.
- Learn to use various instruments for making electrical and electronics measurements using multimeter, oscilloscopes, power supply, electronic switches and relays.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

SEC-II: COMPUTATIONAL PHYSICS
(Credits: 02)

(i) Course learning outcome:

- Learn the importance of computers in solving problems in Physics.
- Learn how to plan for writing the algorithm for solving a problem by drawing the flowchart of simple problems like roots of quadratic equations etc.
- Have a working knowledge about the Linux system, for example, the necessary commands.
- Learn, write and run FORTRAN programs in the Linux system. In particular, they should attempt the following exercises:

  (i) Exercises on syntax on usage of FORTRAN.
  (ii) Usage of GUI windows, Linux commands, familiarity with DOS commands and working in an editor to write sources codes in FORTRAN.
  (iii) To print out all natural even/ odd numbers between given limits.
  (iv) To find maximum, minimum and range of a given set of numbers.

- The students should also learn "Scientific Word Processing", particularly, how to use the LaTeX software in writing articles and papers which include mathematical equations and diagrams. Similarly, students should learn the basics of Gnuplot.
- To have hands-on experience on computational tools, students are expected to do the following exercises:

  (i) to compile a frequency distribution and evaluate mean, standard deviation etc,
  (ii) to evaluate sum of finite series and the area under a curve,
  (iii) to find the product of two matrices
  (iv) to find a set of prime numbers and Fibonacci series,
  (v) to write program to open a file and generate data for plotting using Gnuplot,
  (vi) plotting trajectory of a projectile projected horizontally,
  (vii) plotting trajectory of a projectile projected making an angle with the horizontal direction,

(viii) creating an input Gnuplot file for plotting a data and saving the output for seeing on the screen, saving it as an eps file and as a pdf file,

(ix) to find the roots of a quadratic equation,

(x) numerical solution of equation of motion of simple harmonic oscillator and plot the outputs for visualization,

(xi) Simulate the motion of a particle in a central force field and plot the output for visualization.

(ii) Broad contents of the course:

- Introduction
- Scientific Programming
- Control Statements
- Scientific word processing: Introduction to LATEX
- Visualization

(iii) Skills to be learned

- The students should learn the skills for writing a flow chart and then writing the corresponding program for a specific problem using the C/ C^{++}/FORTRAN language.
- The student should also acquire the proficiency in effectively using the GUI Windows, the LINUX operating system and also in using the LaTeX software for wring a text file.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

SEC-III: ELECTRICAL CIRCUITS AND NETWORK SKILLS (Credits: 02)

(i) Course learning outcome:

- After the completion of the course the student will acquire necessary skills/ hands on experience /working knowledge on multimeters, voltmeters,ammeters, electric circuit elements, dc power sources, ac/dc generators, inductors, capacitors, transformers, single phase and three phase motors, interfacing dc/ac motors to control and measure, relays and basics of electrical wiring.

(ii) Broad contents of the course:

- Basic principles of electricity, electrical circuits and electrical drawings.
- Physics of generators, transformers, electric motors.
- Solid state devices and their uses.
- Electrical wiring and measures for electrical protection.

(iii) Skills to be learned

- Skills to understand various types of DC and AC circuits and making electrical drawings with symbols for various systems.
- Skills to understand and operate generators, transformers and electric motors.
- Develop knowledge of solid state devices and their uses.
- Skills to do electrical wiring with assured electrical protection devices.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

SEC-IV: BASIC INSTRUMENTATION SKILLS
(Credits: 02)

(i) Course learning outcome:

After the successful completion of the course the student is expected to have the necessary working knowledge on accuracy, precision, resolution, range and errors/uncertainty in measurements. He/she will acquire hands on skills in the usage of oscilloscopes, multimeters, multivibrators, rectifiers, amplifiers, oscillators and high voltage probes. He also would have gained knowledge on the working and operations of LCR Bridge, generators, digital meters and counters.

(ii) Broad contents of the course:

- Basics of measurement
- Electronic voltmeters/multimeters
- Cathode ray oscilloscope
- Impedance Bridges and Q meters.
- Digital instruments, Digital multimeters

(iii) Skills to be learned

- Develop skills to use basic electrical instruments like multimeter, electronic voltmeter, cathode ray, and oscilloscope.
- Acquire efficiency in making signal generators and analysis of obtained signals.
- Learn to understand and use various types of digital instruments.
- Develop knowledge of making measurements with Impedance Bridges and Q meters.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

SEC-V: RENEWABLE ENERGY AND ENERGY HARVESTING (Credits: 02)

(i) Course learning outcome:

- The students are expected to learn not only the theories of the renewable sources of energy, but also to have hands-on experiences on them wherever possible. Some of the renewable sources of energy which should be studied here are: (i) off-shore wind energy, (ii) tidal energy, (iii) solar energy, (iv) biogas energy and (v) hydroelectricity.

  All these energy sources should be studied in detail.

- Learn about piezoelectricity, carbon- captured technologies like cells, batteries.
- The students should observe practical demonstrations of (i) training modules of solar energy, wind energy etc., (ii) Conversion of vibration into voltage using piezoelectric materials, (iv) conversion of thermal energy into voltage using thermoelectric modules.

(ii) Broad contents of the course:

- Fossil fuels and Alternate Sources of Energy
- Solar energy
- Wind Energy harvesting
- Ocean Energy
- Geothermal Energy
- Hydro Energy
- Piezoelectric Energy Harvesting
- Electromagnetic Energy Harvesting

(iii) Skills to be learned

- In this course student will study non –conventional energy sources and their practical applications.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

SEC-VI: TECHNICAL DRAWINGS
(Credits: 02)

(i) Course learning outcome:

This course learning will enable the student to be proficient in

- Understanding the concept of a sectional view, what is meant by a cutting plane, how to draw, and learn proper technique for drawing an aligned sections
- With above understanding, he will be exposed to n the use of spatial visualization by constructing an orthographic multi view drawing
- He / she will be expert in drawing simple curves like ellipse, cycloid and spiral, Orthographic projections of points, lines and of solids like cylinders, cones, prisms and pyramids etc.
- Exposure to Computer Aided Design (CAD) and Auto CAD techniques will make the student technologically savvy.

(ii) Broad contents of the course:

- Introduction
- Projection
- Object Projection
- CAD Drawing

(iii) Skills to be learned

Basic understanding of how to read technical maps/draws. stereographic, 2D, 3D projections shall be acquired.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

SEC-VII: RADIATION SAFETY
(Credits: 02)

(i) Course learning outcome:

- Be aware and understand the hazards of radiation and the safety measures to guard against these hazards.
- Revise or learn the basic aspects of the atomic and nuclear Physics, specially the radiations that originate from the atom and the nucleus.
- Have a comprehensive knowledge about the nature of interaction of matter with radiations like gamma, beta, alpha rays, neutrons etc. and radiation shielding by appropriate materials.
- Know about the units of radiations and their safety limits, the devises to detect and measure radiation, such as the Geiger-Mueller counter and scintillation counter.
- The students are expected to learn radiation safety management, biological effects of ionizing radiation, operational limits and basics of radiation hazards evaluation and control, radiation protection standards, 'International Commission on Radiological Protection' (ICRP) its principles, justification, optimization, limitation, introduction of safety and risk management of radiation. nuclear waste and disposal management, brief idea about 'Accelerator driven Sub-critical System' (ADS) for waste management.
- Learn about the devices which apply radiations in medical sciences, such as MRI, PET.
- The students are expected to do the following experiments: (i) Study the background radiation levels using Radiation meter ,
- (ii) Characteristics of Geiger Muller (GM) Counter, getting the plateau curve and the operating voltage and the statistical distribution of beta or gamma ray emitted from a radioactive source,
- Determination of gamma ray linear and mass absorption coefficient of a given material, and drawing the mass absorption coefficient vs. energy curve for a given material with a number of gamma ray sources, (v)study of beta ray energy spectrum for a given source.

(ii) Broad contents of the course:

- Basic of Atomic and Nuclear Physics
- Interaction of Radiation with matter: Types of Radiation
- Radiation detection and monitoring devices: Radiation Quantities and Units
- Radiation safety management
- Application of nuclear techniques

(iii) Skills to be learned

- General concepts of nuclei, nuclear forces and atomic physics are studied.
- Basic knowledge about nuclear radiation types and radiation detectors.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

SEC-VIII: APPLIED OPTICS
(Credits: 02)

(i) Course learning outcome:

This course will enable the student to get

- Familiar with optical phenomena and technology.
- Qualitative understanding of basic lasing mechanism, types of Lasers, characteristics of Laser Light, types of Lasers, and its applications in developing LED, Holography.
- The idea of propagation of electromagnetic wave in a nonlinear media – Fibre optics as an example will enable the student to practice thinking in a logical process, which is essential in science.
- Experiments in this course will allow the students to discuss in peer groups to develop their cooperative skills and reinforce their understanding of concepts.

(ii) Broad contents of the course:

- Sources and Detectors
- Fourier Optics
- Holography
- Photonics: Fibre Optics

(iii) Skills to be learned

This course will help in understanding about the lasers and detectors, Holography, Optical fibre and their applications.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

SEC-IX: WEATHER FORECASTING
(Credits: 02)

(i) Course learning outcome:

- Acquire basic knowledge of the elements of the atmosphere, its composition at various heights, variation of pressure and temperature with height.
- To learn basic techniques to measure temperature and its relation with cyclones and anti-cyclones.
- Knowledge of simple techniques to measure wind speed and its directions, humidity and rainfall. Absorption, emission and scattering of radiations in atmosphere. Radiation laws.
- Knowledge of global wind systems, jet streams, local thunderstorms, tropical cyclones, tornadoes and hurricanes.
- Knowledge of climate and its classification. Understanding various causes of climate change like global warming, air pollution, aerosols, ozone depletion, acid rain.
- Develop skills needed for weather forecasting, mathematical simulations, weather forecasting methods, types of weather forecasting, role of satellite observations in weather forecasting, weather maps etc. Uncertainties in predicting weather based on statistical analysis.
- In the laboratory course, students should be able to learn:

- Principle of the working of a weather Station, Study of Synoptic charts and weather reports.
- Processing and analysis of weather data.
- Exercises in reading of Pressure charts, Surface charts, Wind charts and their analysis.
- Develop ability to do weather forecasts using input data.
- Assign Group Activity to observe and examine:

  i. Sunniest and driest day of the week
  ii. Keep record of daily Temp, Pressure, rainfall and wind velocity
  iii. Prepare regular reports of the above observations and circulate it through the local media for the benefit of local community.

(ii) Broad contents of the course:

- Introduction to atmosphere
- Measuring the weather
- Weather systems
- Climate and climate change
- Basics of weather forecasting

(iii) Skills to be learned

- Learn the physical parameters to describe the basic structure of atmosphere and make their measurements.
- Understand the weather system and learn to measure the parameter describing the weather and its changes.
- Learn basic ideas about climate and physical factors affecting climate change.
- Learn basic physics of weather forecasting.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

NOTE: THE CONTENTS AND THE STRUCTURE OF THE SKILL ENHANCEMENT COURSES (SEC) SHOULD BE MODIFIED TO MAKE IT 4 CREDITS WITH 2 CREDITS FOR THEORY AND 2 CREDITS FOR PRACTICALS / PROJECTS / FIELD WORKSHOP ETC.

6.4.4. Generic Elective Courses (GEC) for Minor Physics Course in the B.Sc.(Hons.) for other mains.

and

Core Courses (CC) and Discipline Specific Elective Courses (DSEC) for B.Sc. (General) Courses with PCM, PMC and PEM combinations

CC-I &GEC-I: MECHANICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

After going through the course, the student should be able to

- Understand the role of vectors and coordinate systems in Physics.
- Write the expression for the moment of inertia about the given axis of symmetry for different uniform mass distributions.
- Explain the conservation of energy, momentum, angular momentum and apply them to basic problems.
- Understand the analogy between translational and rotational dynamics, and application of both motions simultaneously in analyzing rolling with slipping.
- Apply Kepler's law to describe the motion of planets and satellite in circular orbit.
- Explain the phenomena of simple harmonic motion and the properties of systems executing such motions.
- Describe how fictitious forces arise in a non-inertial frame, e.g., why a person sitting in a merry-go-round experiences an outward pull.
- Describe special relativistic effects and their effects on the mass and energy of a moving object.
- In the laboratory course, after acquiring knowledge of how to handle measuring instruments (like screw gauge, vernier callipers, Travelling microscope) student shall embark on verifying various principles learnt in theory. Measuring 'g' using Bar

Pendulum, Kater pendulum and measuring elastic constants of materials, viscous properties of liquids etc.

(ii) Broad contents of the course

- Vectors
- Ordinary Differential Equations
- Laws of Motion
- Momentum and Energy
- Rotational Motion
- Gravitation
- Oscillations
- Elasticity
- Special Theory of Relativity

(iii) Skills to be learned

- Learn basic mathematics like vectors and ordinary different equation and to understand linear and rotational motion.
- Learn basics of Newtonian gravitation theory and central force problem.
- Learn basic ideas about mechanical oscillators.
- Learn elasticity and elastic constants of material and perform experiments to study them.
- Acquire basic knowledge of special theory of relativity.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

CC-II &GEC-II: ELECTRICITY AND MAGNETISM
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

After going through the course, the student should be able to

- Demonstrate Coulomb's law for the electric field, and apply it to systems of point charges as well as line, surface, and volume distributions of charges.
- Explain and differentiate the vector (electric fields, Coulomb's law) and scalar (electric potential, electric potential energy) formalisms of electrostatics.
- Apply Gauss's law of electrostatics to solve a variety of problems.
- Articulate knowledge of electric current, resistance and capacitance in terms of electric field and electric potential.
- Demonstrate a working understanding of capacitors.
- Describe the magnetic field produced by magnetic dipoles and electric currents.
- Explain Faraday-Lenz and Maxwell laws to articulate the relationship between electric and magnetic fields.
- Describe how magnetism is produced and list examples where its effects are observed.
- Apply Kirchhoff's rules to analyze AC circuits consisting of parallel and/or series combinations of voltage sources and resistors and to describe the graphical relationship of resistance, capacitor and inductor.
- Apply various network theorems such as Superposition Theorem, Thevenin Theorem, Norton Theorem, Reciprocity Theorem, Maximum Power Transfer, etc. and their applications in electronics, electrical circuit analysis, and electrical machines.
- In the laboratory course the student will get an opportunity to verify all the above mentioned theorems elaborated above, using simple electric circuits.

(ii) Broad contents of the course:

- Vector Analysis
- Electrostatistics

- Magnetism
- Electromagnetic Induction
- Maxwell's Equation and EM Wave propagation.

(iii) Skills to be learned

- This course will help in understanding basic concepts of electricity and magnetism and their applications.
- Basic course in electrostatics will equips the student with required prerequisites to understand electrodynamics phenomena.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

CC-III& GEC-III: THERMAL PHYSICS AND STATISTICAL MECHANICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Learn the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations. They are also expected to learn Maxwell's thermodynamic relations.
- Know thefundamentals of the kinetic theory of gases, Maxwell-Boltzman distribution law, equipartition of energies, mean free path of molecular collisions, viscosity, thermal conductivity, diffusion and Brownian motion.
- Have a knowledge of the real gas equations, Van der Waal equation of state, the Joule-Thompson effect.
- Learn about the black body radiations, Stefan- Boltzmann's law, Rayleigh-Jean's law and Planck's law and their significances.
- Learn the quantum statistical distributions, viz., the Bose-Einstein statistics and the Fermi-Dirac statistics.

- In the laboratory, the students are expected to perform the following experiments:

  (i) Measurement of Planck's constant using black body radiation,
  (ii) To determine Stefan's Constant,
  (iii) To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method,
  (iv) To determine the temperature co-efficient of resistance by Platinum resistance thermometer,
  (v) To study the variation of thermo emf across two junctions of a thermocouple with temperature,
  (vi) To determine the coefficient of linear expansion by optical lever method.
  (vii) To determine the pressure coefficient of air by constant volume method,
  (viii) To determine the coefficient of linear expansion by travelling microscope,

(ix) To determine the coefficient of thermal conductivity of a bad conductor by Searle's method.

(ii) Broad contents of the course:

- Laws of Thermodynamics
- Thermodynamic Potentials
- Kinetic Theory of Gases
- Theory of Radiation
- Introduction to Statistical Mechanics

(iii) Skills to be learned

- In this course the students should skilled in doing calculations in thermodynamics and in statistical mechanics.
- They should also be proficient in doing calculations with the kinetic theory of ideal and real gases.
- In the laboratory course, the students should acquire the skills of doing basic experiments in thermal physics with the right theoretical explanations of results there from.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

CC-IV & GEC-IV: WAVES AND OPTICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

This course will enable the student to

- Recognize and use a mathematical oscillator equation and wave equation, and derive these equations for certain systems.
- Apply basic knowledge of principles and theories about the behavior of light and the physical environment to conduct experiments.
- Understand the principle of superposition of waves, so thus describe the formation of standing waves.
- Explain several phenomena we can observe in everyday life that can be explained as wave phenomena.
- Use the principles of wave motion and superposition to explain the Physics of polarisation, interference and diffraction.
- Understand the working of selected optical instruments like biprism, interferometer, diffraction grating, and holograms.
- In the laboratory course, student will gain hands-on experience of using various optical instruments and making finer measurements of wavelength of light using Newton Rings experiment, Fresnel Biprism etc. Resolving power of optical equipment can be learnt first hand.
- The motion of coupled oscillators, study of Lissajous figures and behavior of transverse, longitudinal waves can be learnt in this laboratory course.

(ii) Broad contents of the course:

- Superposition of Two Collinear Harmonic Oscillations
- Superposition of Two Perpendicular Harmonic Oscillations
- Waves Motion – General
- Velocity of Waves

- Superposition of Two Harmonics Waves
- Wave Optics
- Interference
- Michelson's Interferometer
- Diffraction
- Fraunhofer Diffraction
- Fresnel Diffraction
- Polarization

(iii) Skills to be learned

- This course in basics of optics will enable the student to understand various optical phenomena, principles, workings and applications optical instruments
- He / she shall develop an understanding of Waves Motion and its properties.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

GEC-V & DSEC-I: DIGITAL, ANALOG AND INSTRUMENTATION
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

After the successful completion of the course the student is expected to master the following

- Difference between analog and digital circuits, Number systems, their interconversions, Basic logic gates and combinational circuits to construct half adders, full adders, subtractors, 4 bit binary Adder -Subtractor and synthesis of circuits using Boolean algebra.
- Working of P and N type semiconductors, P-N junctions, Forward and Reverse biased junctions, LEDs, photodiode and solar cells, p-n-p,n-p-n transistors, different characteristics of CB,CE and CC configurations, load line, gain and biasing for CE amplifiers and classification of amplifiers.
- Operational amplifiers and its characterization, circuits using Op-Amp for making Summing and subtracting circuits, differentiators and integrators
- Criterion for Oscillations, Oscillators and evaluation of frequency of oscillators.
- Oscilloscope (CRO) and applications and usage of oscilloscopes for measuring voltages, currents and study of waveforms, Different rectifiers and voltage regulation using capacitors, Zener diode, Timing IC 555 and to use IC 555 to construct Monostable and Astable multivibrators.
- At the successful completion of the laboratory course the student is expected to acquire hands on skills/ knowledge on the following:-

  i. Measurement of voltage and frequency of a periodic waveform using CRO, construct all logic gates using NAND as a building block, synthesize digital circuits and simplify them using Boolean algebra, construct adders/subtractors and binary adders and Adder-Subtractors

ii. Design monostable/astable multivibrators using IC555, I-V characterization of PN, Zener diodes, design and build CE amplifiers, build Weinbridge oscillators and construct amplifying circuits using IC 741.

(ii) Broad contents of the course:

- Signals and systems based on the parameters
- Discrete-Time Fourier Transform and Z-transform on signals
- Convolution techniques, filters and their classifications.
- Fast Fourier Transforms.
- Digital Filters and their classifications based on the response, design and algorithm.

(iii) Skills to be learned

- Understand the digital and analyse circuits and difference between them. Various logic GATES and their realization using diodes and transistors.
- Conceptualization of Bolear Algebra and its use in constructing logic circuits by various methods and their applications.
- Learn the physics of semiconductor devices. Different types of semiconductors, their use in making transistors and amplifiers and study their characteristics.
- Learn different types of operational amplifiers and oscillators and use them in laboratory experiments to explain their functioning.
- Learn to understand and use various instruments like:

  (i) CRO
  (ii) Power Supply
  (iii) Half wave and full wave rectifiers
  (iv) Zener diodes and their applications
  (v) Multivibrators

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

GEC-VI & DSEC-II: ELEMENTS OF MODERN PHYSICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Know main aspects of the inadequacies of classical mechanics and understand historical development of quantum mechanics and ability to discuss and interpret experiments that reveal the dual nature of matter.
- Understand the theory of quantum measurements, wave packets and uncertainty principle.
- Understand the central concepts of quantum mechanics: wave functions, momentum and energy operator, the Schrodinger equation, time dependent and time independent cases, probability density and the normalization techniques, skill development on problem solving e.g. one dimensional rigid box, tunneling through potential barrier, step potential, rectangular barrier.
- Understanding the properties of nuclei like density, size, binding energy, nuclear forces and structure of atomic nucleus, liquid drop model and nuclear shell model and mass formula.
- Ability to calculate the decay rates and lifetime of radioactive decays like alpha, beta, gamma decay. Neutrinos and its properties and role in theory of beta decay.
- Understand fission and fusion well as nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.
- Understand various interactions of electromagnetic radiation with matter. Electron positron pair creation.
- In the laboratory course, the students will get opportunity to perform the following experiments
- Measurement of Planck's constant by more than one method.
- Verification of the photoelectric effect and determination of the work Function of a metal.
- Determination of the charge of electron and e/m of electron.
- Determination of the ionization potential of atoms.
- Determine the wavelength of the emission lines in the spectrum of Hydrogen atom.

- Determine the absorption lines in the rotational spectrum of molecules.
- Verification of the law of the Radioactive decay and determine the mean life time of a Radioactive Source, Study the absorption of the electrons from Beta decay. Study of the electron spectrum in Radioactive Beta decays of nuclei.
- Plan and Execute 2-3 group projects in the field of Atomic, Molecular and Nuclear Physics in collaboration with other institutions, if, possible where advanced facilities are available.

(ii) Broad contents of the course:

- Failure of classical physics and need for quantum physics.
- Various experiments establishing quantum physics and their interpretation.
- Wave-particle duality, uncertainty relation and their implications.
- Schrodinger equation and its simple applications in one dimensional potential problems of bound states and scattering.
- Elementary introduction of Nuclear Physics with emphasis on

  (i) Nuclear Structure
  (ii) Nuclear Forces
  (iii) Nuclear Decays
  (iv) Fission and Fusion

(iii) Skills to be learned

- Comprehend the failure of classical physics and need for quantum physics.
- Grasp the basic foundation of various experiments establishing the quantum physics by doing the experiments in laboratory and interpreting them.
- Formulate the basic theoretical problems in one, two and three dimensional physics and solve them.
- Learning to apply the basic skills developed in quantum physics to various problems in

  (i) Nuclear Physics
  (ii) Atomic Physics

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

GEC-VII & DSEC-III: MATHEMATICAL PHYSICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

- Revise the knowledge of calculus, vectors, vector calculus. These basic mathematical structures are essential in solving problems in various branches of Physics as well as in engineering.
- Learn the Fourier analysis of periodic functions and their applications in physical problems such as vibrating strings etc.
- Learn about the special functions, such as the Hermite polynomial, the Legendre polynomial, the Laguerre polynomial and Bessel functions and their differential equations and their applications in various physical problems such as in quantum mechanics which they will learn in future courses in detail.
- Learn the beta, gamma and the error functions and their applications in doing integrations.
- Know about the basic theory of errors, their analysis, and estimation with examples of simple experiments in Physics.
- Acquire knowledge of methods to solve partial differential equations with the examples of important partial differential equations in Physics.
- Learn about the complex numbers and their properties, functions of complex numbers and their properties such as analyticity, poles and residues. The students are expected to learn the residue theorem and its applications in evaluating definite integrals.
- In the laboratory course, learn the fundamentals of the C and C++ programming languages and their applications in solving simple physical problems involving interpolations, differentiations, integrations, differential equations as well as finding the roots of equations.

(ii) Broad contents of the course

- Fourier Series
- Special Functions

- Special Integrals
- Partial Differential Equation
- Complex Analysis

(iii) Skills to be learned

- In this course, the students should acquire proficiency in doing calculations with vectors, beta, gamma and error functions, partial differential equations in rectangular, spherical and cylindrical coordinators, Fourier analysis of periodic functions, special functions, polynomials and their differential equations.
- Ability to learn mathematic of complex variables and solve simple problems with relative functions, complex integrals and their applications to physical problems.
- The students should also acquire the skills in writing programs in the C,C++ languages and doing calculations of physical interests with these languages.
- The students should also become proficient in computing integrations and in solving differential equations by various methods.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

GEC-VIII & DSEC-IV: SOLID STATE PHYSICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

At the end of the course the student is expected to learn and assimilate the following.

- A brief idea about crystalline and amorphous substances, about lattice, unit cell, miller indices, reciprocal lattice, concept of Brillouin zones and diffraction of X-rays by crystalline materials.
- Knowledge of lattice vibrations, phonons and in depth of knowledge of Einstein and Debye theory of specific heat of solids.
- At knowledge of different types of magnetism from diamagnetism to ferromagnetism and hysteresis loops and energy loss.
- Secured an understanding about the dielectric and ferroelectric properties of materials.
- Understanding above the band theory of solids and must be able to differentiate insulators, conductors and semiconductors.
- Understand the basic idea about superconductors and their classifications.
- To carry out experiments based on the theory that they have learned to measure the magnetic susceptibility, dielectric constant, trace hysteresis loop. They will also employ to four probe methods to measure electrical conductivity and the hall set up to determine the hall coefficient of a semiconductor.

(ii) Broad contents of the course:

- Crystalline and amorphous substances, lattice, unit cell, miller indices, reciprocal lattice. Brillouin zones and diffraction of X-rays by crystalline materials.
- Lattice vibrations and phonons
- Different types of magnetism
- Dielectric and ferroelectric materials.
- Band theory of solids
- Insulators, conductors and semiconductors.
- Superconductors and their classifications.

(iii) Skills to be learned

- Learn basics of crystal structure and physics of lattice dynamics
- Learn the physics of different types of material like magnetic materials, dielectric materials, metals and their properties.
- Understand the physics of insulators, semiconductor and conductors with special emphasis on the elementary band theory of semiconductors.
- Comprehend the basic theory of superconductors. Type I and II superconductors, their properties and physical concept of BCS theory.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

GEC-IX & DSEC-V: QUANTUM MECHANICS AND APPLICATIONS QUANTUM MECHANICS (Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

This course will enable the student to get familiar with quantum mechanics formulation.

- After an exposition of inadequacies of classical mechanics in explaining microscopic phenomena, quantum theory formulation is introduced through Schrodinger equation.
- The interpretation of wave function of quantum particle and probabilistic nature of its location and subtler points of quantum phenomena are exposed to the student.
- Through understanding the behavior of quantum particle encountering a i) barrier, ii) potential, the student gets exposed to solving non-relativistic hydrogen atom, for its spectrum and eigenfunctions.
- Study of influence of electric and magnetic fields on atoms will help in understanding Stark effect and Zeeman Effect respectively.
- The experiments using Sci-lab will enable the student to appreciate nuances involved in the theory.
- This basic course will form a firm basis to understand quantum many body problems.
- In the laboratory course, with the exposure in computational programming in the computer lab, the student will be in a position to solve Schrodinger equation for ground state energy and wave functions of various simple quantum mechanical one-dimensional and three dimensional potentials.

(ii) Broad contents of the course:

- Time dependent Schrodinger equation
- Time independent Schrodinger equation
- General discussion of bound states in an arbitrary potential
- Quantum Theory of hydrogen-like atoms
- Atoms in Electric and Magnetic Fields
- Atoms in External Magnetic Fields

- Many electron atoms

(iii) Skills to be learned

- This course shall develop an understanding of how to model a given problem such as hydrogen, particle in a box etc. atom etc using wave function, operators and solve them.
- These skills will help in understanding the different Quantum Systems.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

GEC-X & DSEC-VI: EMBEDDED SYSTEM: INTRODUCTION TO MICROCONTROLLERS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

At the successful completion of the course the student is expected to master the following.

- Embedded systems including its generic architecture, design and classifications, Embedded processors and microcontrollers.
- Organization of intel microprocessor 8085, its architecture, pin diagram, timing diagram, instruction set and programming in assembly language.
- Organization of Intel 8051 microcontroller, its architecture, instruction set, programming and its memory organization, timing diagram.
- Input/output operations and manipulation for arithmetic and logical operations.
- Programming with and without interrupt service request.
- Interfacing parallel and serial ADC and DAC.
- Basics of embedded system development and product development with a brief introduction to Arduino.
- Student shall be able to design, fabricate, test and run the programs.

(ii) Broad contents of the course:

- Embedded Systems
- Intel microprocessor 8085.
- Intel 8051 microcontroller, architecture, instruction set, programming and its memory organization, timing diagram.
- Input/output operations and manipulation for arithmetic and logical operations.
- Programming with and without interrupt service request.
- Interfacing parallel and serial ADC and DAC.
- Embedded system development and product development

(iii) Skills to be learned

- Learn the architecture of embedded systems, their classification and application.
- Learn about the microprocessors and the organization of microprocessor based systems.
- Acquire knowledge of microcontrollers and their role in 1/0 port programming and their interface with peripherals.
- Learn about analog to digital and digital to analog convertors.
- Learn basics of Arduino and programming.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

GEC-XI& DSEC-VII: NUCLEAR & PARTICLE PHYSICS
(Credits: 06, Theory-05, Tutorials-01)

(i) Course learning outcome:

- Learn the ground state properties of a nucleus – the constituents and their properties, mass number and atomic number, relation between the mass number and the radius and the mass number, average density, range of force, saturation property, stability curve, the concepts of packing fraction and binding energy, binding energy per nucleon vs. mass number graph, explanation of fusion and fission from the nature of the binding energy graph.
- Know about the nuclear models and their roles in explaining the ground state properties of the nucleus –(i) the liquid drop model, its justification so far as the nuclear properties are concerned, the semi-empirical mass formula, (ii) the shell model, evidence of shell structure, magic numbers, predictions of ground state spin and parity, theoretical deduction of the shell structure, consistency of the shell structure with the Pauli exclusion principles.
- Learn about the process of radioactivity, the radioactive decay law, the emission of alpha, beta and gamma rays, the properties of the constituents of these rays and the mechanisms of the emissions of these rays, outlines of Gamow's theory of alpha decay and Pauli's theory of beta decay with the neutrino hypothesis, the electron capture, the fine structure of alpha particle spectrum, the Geiger-Nuttall law, the radioactive series.
- Learn the basic aspects of nuclear reactions, the Q-value of such reaction and its derivation from conservation laws, the reaction cross-sections, the types of nuclear reactions, direct and compound nuclear reactions, Rutherford scattering by Coulomb potential.
- Learn some basic aspects of interaction of nuclear radiation with matter- interaction of gamma ray by photoelectric effect, Compton scattering and pair production, energy loss due to ionization, Cerenkov radiation.

- Learn about the detectors of nuclear radiations- the Geiger-Mueller counter, the scintillation counter, the photo-multiplier tube, the solid state and semiconductor detectors.
- The students are expected to learn about the principles and basic constructions of particle accelerators such as the Van-de-Graff generator, cyclotron, betatron and synchrotron. They should know about the accelerator facilities in India.
- Gain knowledge on the basic aspects of particle Physics – the fundamental interactions, elementary and composite particles, the classifications of particles: leptons, hadrons (baryons and mesons), quarks, gauge bosons. The students should know about the quantum numbers of particles: energy, linear momentum, angular momentum, isospin, electric charge, colour charge, strangeness, lepton numbers, baryon number and the conservation laws associated with them.

(ii) Broad contents of the course:

- General properties of nuclei
- Nuclear models
- Radioactive decays
- Nuclear reactions
- Interaction of nuclear radiation with matter
- Detectors for nuclear interaction
- Particle accelerators
- Elementary particles and their properties

(iii) Skills to be learned

- Skills to describe and explain the properties of nuclei and derive them from various models of nuclear structure.
- To understand, explain and derive the various theoretical formulation of nuclear disintegration like α decay, β decay and σ decays.
- Develop basic understanding of nuclear reactions and decays with help of theoretical formulate and laboratory experiments.

- Skills to develop basic understanding of the interaction of various nuclear radiation with matter in low and high energy …….
- Ability to understand, construct and operate simple detector systems for nuclear radiation and training to work with various types of nuclear accelerators.
- Develop basic knowledge of elementary particles as fundamental constituent of matter, their properties, conservation laws during their interactions with matter.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

DSEC-VIII: MEDICAL PHYSICS
(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

This course will enable the student to

- Focus on the application of Physics to clinical medicine.
- Gain a broad and fundamental understanding of Physics while developing particular expertise in medical applications.
- Learn about the human body, its anatomy, physiology and biophysics, exploring its performance as a physical machine. Other topics include the Physics of the senses.
- He / She will study diagnostic and therapeutic applications like the ECG, radiation Physics, X-ray technology, ultrasound and magnetic resonance imaging.
- Gain knowledge with reference to working of various diagnostic tools , medical imaging techniques, how ionizing radiation interacts with matter, how it affects living organisms and how it is used as a therapeutic technique and radiation safety practices
- Imparts functional knowledge regarding need for radiological protection and the sources of and approximate level of radiation exposure for treatment purposes.
- In the laboratory course, the student will be exposed to the workings of various medical devices. He / she gets familiarized with various detectors used in medical imaging, medical diagnostics. The hands-on experience will be very useful for the students when he / she enter the job market.

(ii) Broad contents of the course:

- Physics of the Body-I
- Physics of the Body –II
- Physics of Diagnostic and Therapeutic Systems-I
- Radiation Physics
- Medical Imaging Physics
- Radiation Oncology Physics

- Radiation and Radiation Protection
- Physics of Diagnostic and Therapeutic Systems-II

(iii) Skills to be learned

Essential physics of Medical Imaging, Radiological Physics, Therapeutic Systems and Radiation Therapy is acquired.

(iv) The detail contents of this course and references and suggested books are given in Section 6.5.

6.4.5. Ability Enhancement Compulsory Courses (AECC)

- **AECC-1 English**
- **AECC-II MIL Communications**
- **AECC-III Environment Science**

The learning outcomes, broad contents, skills to be learned and detail contents of the course would be designed by the concerned departments.

6.5. Detail Contents of various Courses, the suggested references and books:

THE DEPARTMENT / UNIVERSITY CAN CHANGE / MODIFY THE COURSE CONTENT TO THE EXTENT OF 20% ACCORDING TO THE EXPERTISE AVAILABLE IN THE INSTITUTION AFTER FOLLOWING PROPER PROCEDURES DESCRIBED IN THE STATUTES AND ORDINANCES.

6.5.1. Compulsory Courses (C) and Discipline Specific Elective Courses (DSE) for B.Sc. (Hons.) Physics.

CORE COURSE (HONOURS IN PHYSICS)

Semester I

PHYSICS-C I: MATHEMATICAL PHYSICS-I

(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

The emphasis of course is on applications in solving problems of interest to physicists.

The students are to be examined entirely on the basis of problems, seen and unseen.

Calculus:

Recapitulation: Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions, Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). **(2 Lectures)**

First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems.
Particular Integral. **(13 Lectures)**

Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers. **(6 Lectures)**

Vector Calculus:

Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields. **(5 Lectures)**

Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities. **(8 Lectures)**

Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs). **(14 Lectures)**

Orthogonal Curvilinear Coordinates:

Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems. **(6 Lectures)**

Introduction to probability:

Independent random variables: Probability distribution functions; binomial, Gaussian, and Poisson, with examples. Mean and variance. Dependent events: Conditional Probability.
Bayes' Theorem and the idea of hypothesi testing. **(4 Lectures)**

Dirac Delta function and its properties:

Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function. **(2 Lectures)**

Reference Books:

- Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier.
- An introduction to ordinary differential equations, E.A. Coddington, 2009, PHI learning
- Differential Equations, George F. Simmons, 2007, McGraw Hill.
- Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
- Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book
- Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning
- Mathematical Physics, Goswami, 1st edition, Cengage Learning
- Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
- Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
- Essential Mathematical Methods, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Press.
- Mathematical Physics, H.K. Dass and R. Verma, S. Chand & Company.

PHYSICS LAB- C I LAB:
60 Lectures

The aim of this Lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- Highlights the use of computational methods to solve physical problems
- The course will consist of lectures (both theory and practical) in the Lab
- Evaluation done not on the programming but on the basis of formulating the problem
- Aim at teaching students to construct the computational problem to be solved
- Students can use any one operating system Linux or Microsoft Windows

Topics	Description with Applications
Introduction and Overview	Computer architecture and organization, memory and Input/output devices
Basics of scientific computing	Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow &overflow-emphasize the importance of making equations in terms of dimensionless variables, Iterative methods
Errors and error Analysis	Truncation and round off errors, Absolute and relative errors, Floating point computations.
Review of C & C++ Programming fundamentals	Introduction to Programming, constants, variables and data types, operators and Expressions, I/O statements, scanf and printf, c in and c out, Manipulators for data formatting, Control statements (decision making and looping statements) (If-statement. If-else Statement. Nested if Structure. Else-if Statement. Ternary Operator. Goto Statement. Switch Statement. Unconditional and Conditional Looping. While Loop. Do-While Loop. FOR Loop. Break and Continue Statements. Nested Loops), Arrays (1D & 2D) and strings, user defined functions, Structures and Unions, Idea of classes and objects
Programs:	Sum & average of a list of numbers, largest of a given list of numbers and its location in the list, sorting of numbers in ascending descending order, Binary search
Random number generation	Area of circle, area of square, volume of sphere, value of pi (**π**)

Solution of Algebraic and Transcendental equations by Bisection, Newton Raphson and Secant methods	Solution of linear and quadratic equation, solving $\alpha = \tan\alpha\,; I = I_0\left(\frac{\sin\alpha}{\alpha}\right)^2$ in optics
Interpolation by Newton Gregory Forward and Backward difference formula, Error estimation of linear interpolation	Evaluation of trigonometric functions e.g. *sin θ, cos θ, tan θ, etc.*
Numerical differentiation (Forward and Backward difference formula) and Integration (Trapezoidal and Simpson rules), Monte Carlo method	Given Position with equidistant time data to calculate velocity and acceleration and vice versa. Find the area of B-H Hysteresis loop
Solution of Ordinary Differential Equations (ODE) First order Differential equation Euler, modified Euler and Runge-Kutta (RK) second and fourth order methods	First order differential equation • Radioactive decay • Current in RC, LC circuits with DC source • Newton's law of cooling • Classical equations of motion Attempt following problems using RK 4 order method: • Solve the coupled differential equations $$\frac{dx}{dt} = y + x - \frac{x^3}{3};\ \frac{dy}{dx} = -x$$ for four initial conditions x(0) = 0, y(0) = -1, -2, -3, -4. Plot x vs y for each of the four initial conditions on the same screen for $0 \leq t \leq 15$ The differential equation describing the motion of a pendulum is $\frac{d^2\vartheta}{dt^2} = -sin(\vartheta)$. The pendulum is released from rest at an angular displacement α, i.e. $\vartheta(0) = \alpha$ and $\vartheta'(0) = 0$. Solve the equation for α= 0.1, 0.5 and 1.0 and plot ϑ as a function of time in the range $0 \leq t \leq 8\pi$. Also plot the analytic solution valid for small $\vartheta\left(sin(\vartheta)\right) = \vartheta$

Referred Books:

- Introduction to Numerical Analysis, S.S. Sastry, 5th Edn. , 2012, PHI Learning Pvt. Ltd.
- Schaum's Outline of Programming with C++. J. Hubbard, 2000, McGraw-Hill Pub.
- Numerical Recipes in C: The Art of Scientific Computing, W.H. Pressetal, 3rd Edn. , 2007, Cambridge University Press.
- A first course in Numerical Methods, U.M. Ascher & C. Greif, 2012, PHI Learning.
- Elementary Numerical Analysis, K.E. Atkinson, 3 rd Edn., 2007, Wiley India Edition.
- Numerical Methods for Scientists & Engineers, R.W. Hamming, 1973, Courier Dover Pub.
- An Introduction to computational Physics, T.Pang, 2nd Edn. , 2006,Cambridge Univ. Press
- Computational Physics, Darren Walker, 1st Edn., 2015, Scientific International Pvt. Ltd.

PHYSICS-C II: MECHANICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton'sLaws of Motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum. Impulse. **(6 Lectures)**

Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy. **(4 Lectures)**

Collisions: Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames. **(3 Lectures)**

Rotational Dynamics: Angular momentum of a particle and system of particles.Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation. **(12 Lectures)**

Elasticity: Relation between Elastic constants. Twisting torque on a Cylinder or Wire. **(3 Lectures)**

Fluid Motion: Kinematics of Moving Fluids: Poiseuille's Equation for Flow of a Liquidthrough a Capillary Tube. **(2 Lectures)**

Gravitation and Central Force Motion: Law of gravitation. Gravitational potentialenergy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. **(3 Lectures)**

Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS). **(6 Lectures)**

Oscillations: SHM: Simple Harmonic Oscillations. Differential equation of SHM and itssolution. Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor. **(7 Lectures)**

Non-Inertial Systems: Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of Physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications. Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems. **(4 Lectures)**

Special Theory of Relativity: Michelson-Morley Experiment and its outcome.Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Relativistic transformation of velocity, frequency and wave number. Relativistic addition of velocities. Variation of mass with velocity. Massless Particles. Mass-energy Equivalence. Relativistic Doppler effect. Relativistic Kinematics. Transformation of Energy and Momentum. **(10 Lectures)**

Reference Books:

- An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
- Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
- Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
- Analytical Mechanics, G.R. Fowles and G.L. Cassiday. 2005, Cengage Learning
- Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
- Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.
- University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

Additional Books for Reference

- Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000
- University Physics. F.W Sears, M.W Zemansky, H.D Young 13/e, 1986, Addison Wesley

- Physics for scientists and Engineers with Modern Phys., J.W. Jewett, R.A. Serway, 2010, Cengage Learning
- Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.

PHYSICS LAB-C II LAB
60 Lectures

1. Measurements of length (or diameter) using vernier caliper, screw gauge and travelling microscope.
2. To study the random error in observations.
3. To determine the height of a building using a Sextant.
4. To study the Motion of Spring and calculate (a) Spring constant, (b) **g** and (c) Modulus of rigidity.
5. To determine the Moment of Inertia of a Flywheel.
6. To determine **g** and velocity for a freely falling body using Digital Timing Technique
7. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
8. To determine the Young's Modulus of a Wire by Optical Lever Method.
9. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.
10. To determine the elastic Constants of a wire by Searle's method.
11. To determine the value of g using Bar Pendulum.
12. To determine the value of g using Kater's Pendulum.

Reference Books:

- Advanced Practical Physics for students, B. L. Flint and H.T. Worsnop, 1971, Asia Publishing House
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Edn, 2011, Kitab Mahal
- Engineering Practical Physics, S.Panigrahi & B.Mallick,2015, Cengage Learning India Pvt. Ltd.
- Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press.

Semester II

PHYSICS-C III: ELECTRICITY AND MAGNETISM
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Electric Field and Electric Potential

Electric field: Electric field lines. Electric flux. Gauss' Law with applications to chargedistributions with spherical, cylindrical and planar symmetry. **(6 Lectures)**

Conservative nature of Electrostatic Field. Electrostatic Potential. Laplace's and Poisson equations. The Uniqueness Theorem. Potential and Electric Field of a dipole. Force and Torque on a dipole. **(6 Lectures)**

Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors. Parallel-plate capacitor. Capacitance of an isolated conductor. Method of Images and its application to: (1) Plane Infinite Sheet and (2) Sphere. **(10 Lectures)**

Dielectric Properties of Matter: Electric Field in matter. Polarization, PolarizationCharges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector **D**. Relations between **E**, **P** and **D**. Gauss' Law in dielectrics. **(8 Lectures)**

Magnetic Field: Magnetic force between current elements and definition of MagneticField**B**. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of **B**: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field. **(9 Lectures)**

Magnetic Properties of Matter: Magnetization vector (**M**). Magnetic Intensity (**H**). Magnetic Susceptibility and permeability. Relation between **B, H, M**. Ferromagnetism. B-H curve and hysteresis. **(4 Lectures)**

Electromagnetic Induction: Faraday's Law. Lenz's Law. Self Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field. Introduction to Maxwell's Equations. Charge Conservation and Displacement current. **(6 Lectures)**

Electrical Circuits: AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit. **(4 Lectures)**

Network theorems: Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits. **(4 Lectures)**

Ballistic Galvanometer: Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping. CDR. **(3 Lectures)**

Reference Books:

- Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
- Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
- Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
- Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M. Sands, 2008, Pearson Education
- Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press.
- Electricity and Magnetism, J.H.Fewkes & J.Yarwood. Vol. I, 1991, Oxford Univ. Press.

PHYSICS LAB-C III LAB

60 Lectures

1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.
2. To study the characteristics of a series RC Circuit.
3. To determine an unknown Low Resistance using Potentiometer.
4. To determine an unknown Low Resistance using Carey Foster's Bridge.
5. To compare capacitances using De'Sauty's bridge.
6. Measurement of field strength B and its variation in a solenoid (determine dB/dx)
7. To verify the Thevenin and Norton theorems.
8. To verify the Superposition, and Maximum power transfer theorems.
9. To determine self inductance of a coil by Anderson's bridge.
10. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
11. To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
12. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer
13. Determine a high resistance by leakage method using Ballistic Galvanometer.
14. To determine self-inductance of a coil by Rayleigh's method.
15. To determine the mutual inductance of two coils by Absolute method.

Reference Books:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- Engineering Practical Physics, S.Panigrahi and B.Mallick, 2015, Cengage Learning.
- A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal, 1985, Vani Pub.

PHYSICS-C IV: WAVES AND OPTICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Superposition of Collinear Harmonic oscillations: Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences. **(5 Lectures)**

Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods.
Lissajous Figures with equal an unequal frequency and their uses. **(2 Lectures)**

Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. PlaneProgressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Differential Equation. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave. Water Waves: Ripple and Gravity Waves. **(4 Lectures)**

Velocity of Waves: Velocity of Transverse Vibrations of Stretched Strings. Velocity ofLongitudinal Waves in a Fluid in a Pipe. Newton's Formula for Velocity of Sound.
Laplace's Correction. **(6 Lectures)**

Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String:Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves. **(7 Lectures)**

Wave Optics: Electromagnetic nature of light. Definition and properties of wave front.
Huygens Principle. Temporal and Spatial Coherence. **(3 Lectures)**

Interference: Division of amplitude and wavefront. Young's double slit experiment.

Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings:
Measurement of wavelength and refractive index. **(9 Lectures)**

Interferometer: Michelson Interferometer-(1) Idea of form of fringes (No theoryrequired), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, and (5) Visibility of Fringes. Fabry-Perot interferometer. **(4 Lectures)**

Diffraction: Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula.
(Qualitative discussion only) **(2 Lectures)**

Fraunhofer diffraction: Single slit. Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating. Resolving power of grating. **(8 Lectures)**

Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for PlaneWave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate.
Fresnel's Integral, Fresnel diffraction pattern of a straight edge, a slit and a wire. **(7 Lectures)**

Holography: Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves. Point source holograms. **(3 Lectures)**

Reference Books:

- Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
- Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill
- Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
- Optics, Ajoy Ghatak, 2008, Tata McGraw Hill
- The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
- The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
- Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.

PHYSICS LAB- C IV LAB

60 Lectures

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify $\lambda^2 - T$ law.
2. To investigate the motion of coupled oscillators.
3. To study Lissajous Figures.
4. Familiarization with: Schuster`s focusing; determination of angle of prism.
5. To determine refractive index of the Material of a prism using sodium source.
6. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
7. To determine the wavelength of sodium source using Michelson's interferometer.
8. To determine wavelength of sodium light using Fresnel Biprism.
9. To determine wavelength of sodium light using Newton's Rings.
10. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
11. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
12. To determine dispersive power and resolving power of a plane diffraction grating.

Reference Books:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
- A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal, 1985, Vani Pub.

Semester III

PHYSICS-C V: MATHEMATICAL PHYSICS-II
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures
The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, DirichletConditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series.
Parseval Identity. **(10 Lectures)**

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions (Jo(x) and J1(x)) and Orthogonality. **(24 Lectures)**

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions.
Error Function (Probability Integral). **(4 Lectures)**

Theory of Errors: Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error. Least-squares fit. Error on the slope andintercept of a fitted line. **(6 Lectures)**

Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes. Diffusion Equation. **(14 Lectures)**

Reference Books:

- Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.
- Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.
- Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole.
- Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
- Partial Differential Equations for Scientists & Engineers, S.J. Farlow, 1993, Dover Pub.
- Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
- Mathematical methods for Scientists & Engineers, D.A. McQuarrie, 2003, Viva Books

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PHYSICS LAB-C V LAB

60 Lectures

The aim of this Lab is to use the computational methods to solve physical problems. Course will consist of lectures (both theory and practical) in the Lab. Evaluation done not on the programming but on the basis of formulating the problem

Topics	Description with Applications
Introduction to Numerical computation software Scilab	Introduction to Scilab, Advantages and disadvantages, Scilab environment, Command window, Figure window, Edit window, Variables and arrays, Initialising variables in Scilab, Multidimensional arrays, Subarray, Special values, Displaying output data, data file, Scalar and array operations, Hierarchy of operations, Built in Scilab functions, Introduction to plotting, 2D and 3D plotting (2), Branching Statements and program design, Relational & logical operators, the while loop, for loop, details of loop operations, break & continue statements, nested loops, logical arrays and vectorization (2) User defined functions, Introduction to Scilab functions, Variable passing in Scilab, optional arguments, preserving data between calls to a function, Complex and Character data, string function, Multidimensional arrays (2) an introduction to Scilab file processing, file opening and closing, Binary I/o functions, comparing binary and formatted functions, Numerical methods and developing the skills of writing a program (2).
Curve fitting, Least square fit, Goodness of fit, standard deviation	Ohms law to calculate R, Hooke's law to calculate spring Constant
Solution of Linear system of equations by Gauss elimination method and Gauss Seidal method. Diagonalization of matrices, Inverse of a matrix, Eigen vectors, eigen values problems	Solution of mesh equations of electric circuits (3 meshes) Solution of coupled spring mass systems (3 masses)
Generation of Special functions using User defined functions in Scilab	Generating and plotting Legendre Polynomials Generating and plotting Bessel function
Solution of ODE First order Differential equation Euler, modified Euler and Runge-Kutta second order methods Second order differential equation Fixed difference method Partial differential equations	First order differential equation • Radioactive decay • Current in RC, LC circuits with DC source • Newton's law of cooling • Classical equations of motion Second order Differential Equation • Harmonic oscillator (no friction) • Damped Harmonic oscillator • Over damped • Critical damped • Oscillatory • Forced Harmonic oscillator • Transient and • Steady state solution

	Apply above to LCR circuits also Solve $x^2\frac{d^2y}{dx^2} - 4x(1+x)\frac{dy}{dx} + 2(1+x) = x^3$ with the boundary conditions at x = 1, y = $\frac{1}{2}e^2, \frac{dy}{dx} = -\frac{3}{2}e^2 - 0.5$, in the range $1 \le x \le 3$. Plot y and $\frac{dy}{dx}$ against x in the given range on the same graph. Partial Differential Equation: • Wave equation • Heat equation • Poisson equation • Laplace equation
Using Scicos / xcos	• Generating square wave, sine wave, saw tooth wave • Solution to harmonic oscillator • Study of beat phenomenon • Phase space plots

Reference Books:

- Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
- Complex Variables, A.S. Fokas & M.J. Ablowitz, 8th Ed., 2011, Cambridge Univ. Press
- First course in complex analysis with applications, D.G. Zill and P.D. Shanahan, 1940, Jones & Bartlett
- Computational Physics, D.Walker, 1st Edn., 2015, Scientific International Pvt. Ltd.
- A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A.V. Wouwer, P. Saucez, C.V. Fernández. 2014 Springer
- Scilab by example: M. Affouf 2012, ISBN: 978-1479203444
- Scilab (A free software to Matlab): H.Ramchandran, A.S.Nair. 2011 S.Chand & Company
- Scilab Image Processing: Lambert M. Surhone. 2010 Betascript Publishing
- www.**scilab**.in/textbook_companion/generate_book/291

PHYSICS-C VI: THERMAL PHYSICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures
(Include related problems for each topic)

Introduction to Thermodynamics

Zeroth and First Law of Thermodynamics: Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient. **(8 Lectures)**

Second Law of Thermodynamics: Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine

& efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale. **(10 Lectures)**

Entropy: Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero. **(7 Lectures)**

Thermodynamic Potentials: Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations. **(7 Lectures)**

Maxwell's Thermodynamic Relations: Derivations and applications of Maxwell'sRelations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of C_p-C_v, (3) TdS Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process. **(7 Lectures)**

Kinetic Theory of Gases

Distribution of Velocities: Maxwell-Boltzmann Law of Distribution of Velocities in anIdeal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. **(7 Lectures)**

Molecular Collisions: Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance. **(4 Lectures)**

Real Gases: Behavior of Real Gases: Deviations from the Ideal Gas Equation. TheVirial Equation. Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. P-V Diagrams. Joule's Experiment. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule-Thomson Cooling. **(10 Lectures)**

Reference Books:

- Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
- A Treatise on Heat, Meghnad Saha, and B.N.Srivastava, 1958, Indian Press
- Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
- Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.
- Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University Press
- Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.
- Thermal Physics, B.K. Agrawal, Lok Bharti Publications.

PHYSICS LAB- C VI LAB
60 Lectures

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
3. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.

4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
5. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
6. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.
7. To calibrate a thermocouple to measure temperature in a specified Range using (1) Null Method, (2) Direct measurement using Op-Amp difference amplifier and to determine Neutral Temperature.

Reference Books:

- Advanced Practical Physics for students, B. L. Flint and H.T. Worsnop, 1971, Asia Publishing House
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Laboratory Manual of Physics for undergraduate classes,D.P.Khandelwal,1985, Vani Pub.

PHYSICS-C VII: DIGITAL SYSTEMS AND APPLICATIONS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Introduction to CRO: Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference. **(3 Lectures)**

Integrated Circuits(Qualitative treatment only): Active & Passive components.Discrete components. Wafer. Chip. Advantages and drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only). Classification ofICs. Examples of Linear and Digital lCs. **(3 Lectures)**

Digital Circuits: Difference between Analog and Digital Circuits. Binary Numbers.Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers. **(6 Lectures)**

Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of LogicCircuit using Boolean Algebra. Fundamental Products. Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map. **(6 Lectures)**

Data processing circuits: Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders. **(4 Lectures)**

Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor. **(5 Lectures)**

Sequential Circuits: SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop.
M/S JKFlip-Flop. **(6 Lectures)**

Timers: IC 555: block diagram and applications: Astable multivibrator and Monostable multivibrator. **(3 Lectures)**

Shift registers: Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits). **(2 Lectures)**

Counters (4 bits): Ring Counter. Asynchronous counters, Decade Counter. Synchronous Counter. **(4 Lectures)**

Computer Organization: Input/output Devices. Data storage (idea of RAM and ROM).Computer memory. Memory organization & addressing. Memory Interfacing. MemoryMap. **(6 Lectures)**

Intel 8085 Microprocessor Architecture: Main features of 8085. Block diagram. Components. Pin-out diagram. Buses. Registers. ALU. Memory. Stack memory. Timing And Control circuitry.
Timing states. Instruction cycle, Timing diagram of MOV and MVI. **(8 Lectures)**

Introduction to Assembly Language: 1 byte, 2 byte & 3 byte instructions. **(4 Lectures)**

Reference Books:

- Digital Principles and Applications, A.P. Malvino, D.P.Leach and Saha, 7th Ed., 2011, Tata McGraw
- Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.
- Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
- Digital Electronics G K Kharate ,2010, Oxford University Press
- Digital Systems: Principles & Applications, R.J.Tocci, N.S.Widmer, 2001, PHI Learning
- Logic circuit design, Shimon P. Vingron, 2012, Springer.
- Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
- Digital Electronics, S.K. Mandal, 2010, 1st edition, McGraw Hill
- Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Goankar, Prentice Hall.

PHYSICS PRACTICAL-C VII LAB
60 Lectures

1. To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO.
2. To test a Diode and Transistor using a Multimeter.
3. To design a switch (NOT gate) using a transistor.
4. To verify and design AND, OR, NOT and XOR gates using NAND gates.
5. To design a combinational logic system for a specified Truth Table.

6. To convert a Boolean expression into logic circuit and design it using logic gate ICs.
7. To minimize a given logic circuit.
8. Half Adder, Full Adder and 4-bit binary Adder.
9. Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder I.C.
10. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.
11. To build JK Master-slave flip-flop using Flip-Flop ICs
12. To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagram.
13. To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs.
14. To design an astable multivibrator of given specifications using 555 Timer.
15. To design a monostable multivibrator of given specifications using 555 Timer.
16. Write the following programs using 8085 Microprocessor
    a) Addition and subtraction of numbers using direct addressing mode
    b) Addition and subtraction of numbers using indirect addressing mode
    c) Multiplication by repeated addition.
    d) Division by repeated subtraction.
    e) Handling of 16-bit Numbers.
    f) Use of CALL and RETURN Instruction.
    g) Block data handling.
    h) Other programs (e.g. Parity Check, using interrupts, etc.).

Reference Books:

- Modern Digital Electronics, R.P. Jain, 4th Edition, 2010, Tata McGraw Hill.
- Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-Graw Hill.
- Microprocessor Architecture Programming and applications with 8085, R.S. Goankar, 2002, Prentice Hall.
- Microprocessor 8085:Architecture, Programming and interfacing, A. Wadhwa, 2010, PHI Learning.

Semester IV

PHYSICS-VIII: MATHEMATICAL PHYSICS-III

(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.

Complex Analysis: Brief Revision of Complex Numbers and their GraphicalRepresentation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals. **(30 Lectures)**

Integrals Transforms: Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric, Gaussian, finite wave train & other functions. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations. **(15 Lectures)**

Laplace Transforms: Laplace Transform (LT) of Elementary functions. Properties ofLTs: Change of Scale Theorem, Shifting Theorem. LTs of 1^{st} and 2^{nd} order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2^{nd} order Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1^{st} order. Solution of heat flow along infinite bar using Laplace transform. **(15 Lectures)**

Reference Books:

- Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
- Mathematics for Physicists, P. Dennery and A.Krzywicki, 1967, Dover Publications
- Complex Variables, A.S.Fokas & M.J.Ablowitz, 8th Ed., 2011, Cambridge Univ. Press
- Complex Variables, A.K. Kapoor, 2014, Cambridge Univ. Press
- Complex Variables and Applications, J.W. Brown & R.V. Churchill, 7th Ed. 2003, Tata McGraw-Hill
- First course in complex analysis with applications, D.G. Zill and P.D. Shanahan, 1940, Jones & Bartlett

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PHYSICS PRACTICAL-C VIII LAB

60 Lectures

Scilab/C++ based simulations experiments based on Mathematical Physics problems like

1. Solve differential equations:
   $dy/dx = e^{-x}$ with $y = 0$ for $x = 0$

   $dy/dx + e^{-x}y = x^2$

   $d^2y/dt^2 + 2\, dy/dt = -y$

   d2y/dt2 + e-tdy/dt = -y
2. Dirac Delta Function:

   Evaluate $\frac{1}{\sqrt{2\pi\alpha^2}}\int e^{\frac{-(x-2)^2}{2\sigma^2}}(x+3)dx$ for $\sigma = 1, 0.1, 0.01$ and show it tends to 5.
3. Fourier Series:

   Program to sum $\sum_{n=1}^{\infty} 0.2^n$

   Evaluate the Fourier coefficients of a given periodic function (square wave)
4. Frobenius method and Special functions:

   $$\int_{-1}^{1} P_n(\mu)P_m(\mu)\, d\mu = \delta_{n,m}$$

   Plot $P_n(x)$, $j_v(x)$

   Show recursion relation
5. Calculation of error for each data point of observations recorded in experiments done in previous semesters (choose any two).

6. Calculation of least square fitting manually without giving weightage to error. Confirmation of least square fitting of data through computer program.

7. Evaluation of trigonometric functions e.g. *sin θ,* Given Bessel's function at N points find its value at an intermediate point. Complex analysis: Integrate $1/(x^2+2)$ numerically and check with computer integration.

8. Compute the n^{th} roots of unity for $n = 2, 3$, and 4.

9. Find the two square roots of $-5+12j$.

10. Integral transform: FFT of

11. Solve Kirchoff's Current law for any node of an arbitrary circuit using Laplace's transform.

12. Solve Kirchoff's Voltage law for any loop of an arbitrary circuit using Laplace's transform.

13. Perform circuit analysis of a general LCR circuit using Laplace's transform.

Reference Books:

- Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
- Mathematics for Physicists, P. Dennery and A. Krzywicki, 1967, Dover Publications
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896
- A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
- Scilab by example: M. Affouf, 2012. ISBN: 978-1479203444
- Scilab (A free software to Matlab): H.Ramchandran, A.S.Nair. 2011 S.Chand & Company
- Scilab Image Processing: Lambert M. Surhone. 2010 Betascript Publishing
- https://web.stanford.edu/~boyd/ee102/**laplace**_ckts.pdf
- ocw.nthu.edu.tw/ocw/upload/12/244/12handout.pdf

PHYSICS-C IX: ELEMENTS OF MODERN PHYSICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Planck's quantum, Planck's constant and light as a collection of photons; Blackbody Radiation: Quantum theory of Light; Photo-electric effect and Compton scattering. De Broglie wavelength and matter waves; Davisson-Germer experiment. Wave description of particles by wave packets. Group and Phase velocities and relation between them. Two-Slit experiment with electrons. Probability. Wave amplitude and wave functions. **(14 Lectures)**

Position measurement- gamma ray microscope thought experiment; Wave-particle duality, Heisenberg uncertainty principle (Uncertainty relations involving Canonical pair of variables): Derivation from Wave Packets impossibility of a particle following a trajectory; Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle- application to virtual particles and range of an interaction. **(5 Lectures)**

Two slit interference experiment with photons, atoms and particles; linear superposition principle as a consequence; Matter waves and wave amplitude; Schrodinger equation for non-relativistic particles; Momentum and Energy operators; stationary states; physical interpretation of a wave function, probabilities and normalization; Probability and probability current densities in one dimension. **(10 Lectures)**

One dimensional infinitely rigid box- energy eigenvalues and eigenfunctions, normalization; Quantum dot as example; Quantum mechanical scattering and tunnelling in one dimension-across a step potential & rectangular potential barrier. **(10 Lectures)**

Size and structure of atomic nucleus and its relation with atomic weight; Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle. Nature of nuclear force, NZ graph, Liquid Drop model: semi-empirical mass formula and binding energy, Nuclear Shell Model and magic numbers. **(6 Lectures)**

Radioactivity: stability of the nucleus; Law of radioactive decay; Mean life and half-life; Alpha decay; Beta decay- energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus. **(8 Lectures)**

Fission and fusion- mass deficit, relativity and generation of energy; Fission - nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium 235; Fusion and thermonuclear reactions driving stellar energy
(brief qualitative discussions). **(3 Lectures)**

Lasers: Einstein's A and B coefficients. Metastable states. Spontaneous and Stimulatedemissions. Optical Pumping and Population Inversion. Three-Level and Four-Level Lasers. Ruby Laser and He-Ne Laser. Basic lasing. **(4 Lectures)**

Reference Books:

- Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
- Introduction to Modern Physics, Rich Meyer, Kennard, Coop, 2002, Tata McGraw Hill
- Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.
- Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.
- Modern Physics, G.Kaur and G.R. Pickrell, 2014, McGraw Hill
- Quantum Mechanics: Theory & Applications, A.K.Ghatak & S.Lokanathan, 2004, Macmillan

Additional Books for Reference

- Modern Physics, J.R. Taylor, C.D. Zafiratos, M.A. Dubson, 2004, PHI Learning.
- Theory and Problems of Modern Physics, Schaum`s outline, R. Gautreau and W. Savin, 2nd Edn, Tata McGraw-Hill Publishing Co. Ltd.
- Quantum Physics, Berkeley Physics, Vol.4. E.H.Wichman, 1971, Tata McGraw-Hill Co.
- Basic ideas and concepts in Nuclear Physics, K.Heyde, 3rd Edn., Institute of Physics Pub.
- Six Ideas that Shaped Physics: Particle Behave like Waves, T.A.Moore, 2003, McGraw Hill
- Quantum Mechanics, R. Eisberg and R. Resnick, John Wiley & Sons.

PHYSICS PRACTICAL-C IX LAB
60 Lectures

1. Measurement of Planck's constant using black body radiation and photo-detector
2. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
3. To determine work function of material of filament of directly heated vacuum diode.
4. To determine the Planck's constant using LEDs of at least 4 different colours.
5. To determine the wavelength of H-alpha emission line of Hydrogen atom.
6. To determine the ionization potential of mercury.
7. To determine the absorption lines in the rotational spectrum of Iodine vapour.
8. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
9. To setup the Millikan oil drop apparatus and determine the charge of an electron.
10. To show the tunneling effect in tunnel diode using I-V characteristics.
11. To determine the wavelength of laser source using diffraction of single slit.
12. To determine the wavelength of laser source using diffraction of double slits.
13. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating

Reference Books

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Edn, 2011,Kitab Mahal

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PHYSICS-C X: ANALOG SYSTEMS AND APPLICATIONS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Semiconductor Diodes: P and N type semiconductors. Energy Level Diagram.Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and

Reverse Biased Diode. Drift Velocity. Derivation for Barrier Potential, Barrier Width and Current for Step Junction.

Current Flow Mechanismin Forward and Reverse Biased Diode. **(10 Lectures)**

Two-terminal Devices and their Applications: (1) Rectifier Diode: Half-waveRectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter (2) Zener Diode and Voltage Regulation. Principle and structure of (1) LEDs, (2) Photodiode and (3) Solar Cell. **(6 Lectures)**

Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CEand CC Configurations. Current gains α and β Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff and Saturation Regions. **(6 Lectures)**

Amplifiers: Transistor Biasing and Stabilization Circuits. Fixed Bias and VoltageDivider Bias. Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains. Classification of Class A, B & C Amplifiers. **(10 Lectures)**

Coupled Amplifier: Two stage RC-coupled amplifier and its frequency response. **(4 Lectures)**

Feedback in Amplifiers: Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. **(4 Lectures)**

Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phaseshift oscillator, determination of Frequency. Hartley & Colpitts oscillators. **(4 Lectures)**

Operational Amplifiers (Black Box approach): Characteristics of an Ideal andPractical Op-Amp. (IC 741) Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground. **(4 Lectures)**

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3)Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Zero crossingdetector (8) Wein bridge oscillator. **(9 Lectures)**

Conversion: Resistive network (Weighted and R-2R Ladder). Accuracy and Resolution. A/D Conversion (successive approximation) **(3 Lectures)**

Reference Books:

- Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
- Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
- Solid State Electronic Devices, B.G.Streetman & S.K.Banerjee, 6th Edn.,2009, PHI Learning
- Electronic Devices & circuits, S.Salivahanan & N.S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
- OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
- Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6th Edn., Oxford University Press.
- Electronic circuits: Handbook of design & applications, U.Tietze, C.Schenk,2008, Springer
- Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd Ed., 2002, Wiley India
- Microelectronic Circuits, M.H. Rashid, 2nd Edition, Cengage Learning
- Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India

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PHYSICS PRACTICAL-C X LAB
60 Lectures

1. To study V-I characteristics of PN junction diode, and Light emitting diode.
2. To study the V-I characteristics of a Zener diode and its use as voltage regulator.
3. Study of V-I & power curves of solar cells, and find maximum power point & efficiency.
4. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
5. To study the various biasing configurations of BJT for normal class A operation.
6. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
7. To study the frequency response of voltage gain of a RC-coupled transistor amplifier.
8. To design a Wien bridge oscillator for given frequency using an op-amp.
9. To design a phase shift oscillator of given specifications using BJT.

10. To study the Colpitt`s oscillator.
11. To design a digital to analog converter (DAC) of given specifications.
12. To study the analog to digital convertor (ADC) IC.
13. To design an inverting amplifier using Op-amp (741,351) for dc voltage of given gain
14. To design inverting amplifier using Op-amp (741,351) and study its frequency response
15. To design non-inverting amplifier using Op-amp (741,351) & study its frequency response
16. To study the zero-crossing detector and comparator
17. To add two dc voltages using Op-amp in inverting and non-inverting mode
18. To design a precision Differential amplifier of given I/O specification using Op-amp.
19. To investigate the use of an op-amp as an Integrator.
20. To investigate the use of an op-amp as a Differentiator.
21. To design a circuit to simulate the solution of a $1^{st}/2^{nd}$ order differential equation.

Reference Books:

- Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-Graw Hill.
- OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4^{th} edition, 2000, Prentice Hall.
- Electronic Principle, Albert Malvino, 2008, Tata Mc-Graw Hill.
- Electronic Devices & circuit Theory, R.L. Boylestad & L.D. Nashelsky, 2009, Pearson

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Semester V

PHYSICS-C XI: QUANTUM MECHANICS AND APPLICATIONS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Time dependent Schrodinger equation: Time dependent Schrodinger equation anddynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation valuesof position and momentum. Wave Function of a Free Particle. **(6 Lectures)**

Time independent Schrodinger equation-Hamiltonian, stationary states and energyeigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction; Position-momentum uncertainty principle. **(10 Lectures)**

General discussion of bound states in an arbitrary potential- continuity of wavefunction, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method; Hermitepolynomials; ground state, zero point energy & uncertainty principle. **(12 Lectures)**

Quantum theory of hydrogen-like atoms: time independent Schrodinger equation inspherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wavefunctions from Frobenius method; shapes of the probability densities for ground & first excited states; Orbital angular momentum quantum numbers l and m; s, p, d,.. shells. **(10 Lectures)**

Atoms in Electric & Magnetic Fields: Electron angular momentum. Spacequantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. **(8 Lectures)**

Atoms in External Magnetic Fields:- Normal and Anomalous Zeeman Effect. Paschen Back and Stark Effect (Qualitative Discussion only). **(4 Lectures)**

Many electron atoms: Pauli's Exclusion Principle. Symmetric & Antisymmetric WaveFunctions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Vector Model. Spin-orbit coupling in atoms-L-S and J-J couplings. Hund's Rule.
Term symbols. Spectra of Hydrogen and AlkaliAtoms (Na etc.). **(10 Lectures)**

Reference Books:

- A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan, 2nd Ed., 2010, McGraw Hill
- Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
- Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
- Quantum Mechanics, G. Aruldhas, 2nd Edn. 2002, PHI Learning of India.
- Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.
- Quantum Mechanics: Foundations & Applications, Arno Bohm, 3rd Edn., 1993, Springer
- Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press

Additional Books for Reference

- Quantum Mechanics, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.
- Introduction to Quantum Mechanics, D.J. Griffith, 2nd Ed. 2005, Pearson Education
- Quantum Mechanics, Walter Greiner, 4th Edn., 2001, Springer

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PHYSICS PRACTICAL-C XI LAB

60 Lectures

Use C/C++/Scilab for solving the following problems based on Quantum Mechanics like

1. Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom:

   $\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$ where $V(r) = -\frac{e^2}{r}$

   Here, m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take e = 3.795 $(eVÅ)^{1/2}$, ħc = 1973 (eVÅ) and m = 0.511x10^6 eV/c^2.

2. Solve the s-wave radial Schrodinger equation for an atom:

   $\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$

   where m is the reduced mass of the system (which can be chosen to be the mass of an electron), for the screened coulomb potential $V(r) = -\frac{e^2}{r}e^{-r/a}$

   Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take e = 3.795 $(eVÅ)^{1/2}$, m = 0.511x10^6 eV/c^2, and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973 (eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

3. Solve the s-wave radial Schrodinger equation for a particle of mass m:

   $\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$

   For the anharmonic oscillator potential $V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$

   for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose m = 940 MeV/c^2, k = 100MeV fm^{-2}, b = 0, 10, 30 MeV fm^{-3} In these units, cħ = 197.3 MeV fm. The ground state energy I expected to lie between 90 and 110 MeV for all three cases.

4. Solve the s-wave radial Schrodinger equation for the vibrations of hydrogen molecule:

   $\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2\mu}{\hbar^2}[V(r) - E]$Where μ is the reduced mass of the two-atom system for the Morse potential $V(r) = D\left(e^{-2\alpha r'} - e^{-\alpha r'}\right), r' = \frac{r - r_0}{r}$

   Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.

   Take: m = 940x10^6 eV/C^2, D = 0.755501 eV, α = 1.44, r_o = 0.131349 Å

Laboratory based experiments:

5. Study of Electron spin resonance- determine magnetic field as a function of the resonance frequency
6. Study of Zeeman effect: with external magnetic field; Hyperfine splitting
7. To show the tunneling effect in tunnel diode using I-V characteristics.
8. Quantum efficiency of CCDs

Reference Books:

- Schaum's outline of Programming with C++. J.Hubbard, 2000,McGraw-Hill Publication
- Numerical Recipes in C: The Art of Scientific Computing, W.H. Pressetal., 3rd Edn., 2007, Cambridge University Press.
- An introduction to computational Physics, T.Pang, 2nd Edn.,2006, Cambridge Univ. Press
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific & Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández.2014 Springer.
- Scilab (A Free Software to Matlab): H. Ramchandran, A.S. Nair. 2011 S. Chand & Co.
- A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
- Scilab Image Processing: L.M.Surhone.2010 Betascript Publishing ISBN:978-6133459274

PHYSICS-C XII: SOLID STATE PHYSICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Crystal Structure: Solids: Amorphous and Crystalline Materials. Lattice TranslationVectors. Lattice with a Basis – Central and Non-Central Elements. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor. **(12 Lectures)**

Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Monoatomicand Diatomic Chains. Acoustical and Optical Phonons. Qualitative description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories ofspecific heat of solids. T^3 law **(10 Lectures)**

Magnetic Properties of Matter: Dia-, Para-, Ferri- and Ferromagnetic Materials.Classical Langevin Theory of dia– and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss. **(8 Lectures)**

Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom.Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons, TO modes. **(8 Lectures)**

Ferroelectric Properties of Materials: Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop. **(6 lectures)**

Elementary band theory: Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (04 probe method) & Hall coefficient. **(10 Lectures)**

Superconductivity: Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation) **(6 Lectures)**

Reference Books:

- Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
- Elements of Solid State Physics, J.P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
- Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
- Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning
- Solid-state Physics, H. Ibach and H. Luth, 2009, Springer
- Solid State Physics, Rita John, 2014, McGraw Hill
- Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
- Solid State Physics, M.A. Wahab, 2011, Narosa Publications

PHYSICS PRACTICAL-C XII LAB

60 Lectures

1. Measurement of susceptibility of paramagnetic solution (Quinck`s Tube Method)
2. To measure the Magnetic susceptibility of Solids.
3. To determine the Coupling Coefficient of a Piezoelectric crystal.
4. To measure the Dielectric Constant of a dielectric Materials with frequency
5. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR)
6. To determine the refractive index of a dielectric layer using SPR
7. To study the PE Hysteresis loop of a Ferroelectric Crystal.
8. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
9. To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150 ^{o}C) and to determine its band gap.
10. To determine the Hall coefficient of a semiconductor sample.

Reference Books:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
- A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal
- Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India.

Semester VI

PHYSICS-C XIII: ELECTROMAGNETIC THEORY
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Maxwell Equations: Review of Maxwell’s equations. Displacement Current. Vectorand Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density,
Momentum Density and Angular Momentum Density. **(12 Lectures)**

EM Wave Propagation in Unbounded Media: Plane EM waves through vacuum andisotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth. Wave propagation through dilute plasma, electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth, application to propagation through ionosphere. **(10 Lectures)**

EM Wave in Bounded Media: Boundary conditions at a plane interface between twomedia. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reflection (normal Incidence) **(10 Lectures)**

Polarization of Electromagnetic Waves: Description of Linear, Circular and EllipticalPolarization. Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel’s Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Babinet Compensator and its Uses. Analysis of Polarized Light **(12 Lectures)**

Rotatory Polarization: Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification ofFresnel's theory. Specific rotation. Laurent's half-shade polarimeter. **(5 Lectures)**

Wave Guides: Planar optical wave guides. Planar dielectric wave guide. Condition ofcontinuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves. Field energy and Power transmission. **(8 Lectures)**

Optical Fibres:- Numerical Aperture. Step and Graded Indices (Definitions Only). Single and Multiple Mode Fibres (Concept and Definition Only). **(3 Lectures)**

Reference Books:

- Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
- Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
- Introduction to Electromagnetic Theory, T.L. Chow, 2006, Jones & Bartlett Learning
- Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill
- Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning
- Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.
- Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer

Additional Books for Reference

- Electromagnetic Fields & Waves, P.Lorrain & D.Corson, 1970, W.H.Freeman & Co.
- Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
- Electromagnetic field theory fundamentals, B. Guru and H. Hiziroglu, 2004,Cambridge University Press

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PHYSICS PRACTICAL-C XIII LAB
60 Lectures

1. To verify the law of Malus for plane polarized light.
2. To determine the specific rotation of sugar solution using Polarimeter.
3. To analyze elliptically polarized Light by using a Babinet's compensator.
4. To study dependence of radiation on angle for a simple Dipole antenna.

5. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
6. To study the reflection, refraction of microwaves
7. To study Polarization and double slit interference in microwaves.
8. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
9. To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
10. To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.
11. To verify the Stefan`s law of radiation and to determine Stefan's constant.
12. To determine the Boltzmann constant using V-I characteristics of PN junction diode.

Reference Books:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal
- Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer

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PHYSICS-C XIV: STATISTICAL MECHANICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Classical Statistics: Macrostate & Microstate, Elementary Concept of Ensemble, PhaseSpace, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to Specific Heat and its Limitations, Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature. **(18 Lectures)**

Classical Theory of Radiation: Properties of Thermal Radiation. Blackbody Radiation.Pure temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Saha's Ionization Formula. Rayleigh-Jean's Law. Ultraviolet Catastrophe. **(9 Lectures)**

Quantum Theory of Radiation: Spectral Distribution of Black Body Radiation.Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law. **(5 Lectures)**

Bose-Einstein Statistics: B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law. **(13 Lectures)**

Fermi-Dirac Statistics: Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit. **(15 Lectures)**

Reference Books:

- Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
- Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
- Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall
- Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
- An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press

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PHYSICS PRACTICAL-C XIV LAB
60 Lectures

Use C/C^{++}/Scilab/other numerical simulations for solving the problems based on Statistical Mechanics like

1. Computational analysis of the behavior of a collection of particles in a box that satisfy Newtonian mechanics and interact via the Lennard-Jones potential, varying the total number of particles N and the initial conditions:
   a) Study of local number density in the equilibrium state (i) average; (ii) fluctuations
   b) Study of transient behavior of the system (approach to equilibrium)
   c) Relationship of large N and the arrow of time
   d) Computation of the velocity distribution of particles for the system and comparison with the Maxwell velocity distribution
   e) Computation and study of mean molecular speed and its dependence on particle mass
   f) Computation of fraction of molecules in an ideal gas having speed near the most probable speed
2. Computation of the partition function Z(β) for examples of systems with a finite number of single particle levels (e.g., 2 level, 3 level, etc.) and a finite number of non-interacting particles N under Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics:
   a) Study of how Z(β), average energy <E>, energy fluctuation ΔE, specific heat at constant volume Cv, depend upon the temperature, total number of particles N and the spectrum of single particle states.
   b) Ratios of occupation numbers of various states for the systems considered above
   c) Computation of physical quantities at large and small temperature T and comparison of various statistics at large and small temperature T.
3. Plot Planck's law for Black Body radiation and compare it with Raleigh-Jeans Law at high temperature and low temperature.
4. Plot Specific Heat of Solids (a) Dulong-Petit law, (b) Einstein distribution function, (c) Debye distribution function for high temperature and low temperature and compare them for these two cases.
5. Plot the following functions with energy at different temperatures
   a) Maxwell-Boltzmann distribution

b) Fermi-Dirac distribution

c) Bose-Einstein distribution

Reference Books:

- Elementary Numerical Analysis, K.E.Atkinson, 3 r d E d n . 2 0 0 7, Wiley India Edition
- Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
- Introduction to Modern Statistical Mechanics, D. Chandler, Oxford University Press, 1987
- Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
- Statistical and Thermal Physics with computer applications, Harvey Gould and Jan Tobochnik, Princeton University Press, 2010.
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientificand Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014Springer ISBN: 978-3319067896Scilab by example: M. Affouf, 2012. ISBN: 978-1479203444
- Scilab Image Processing: L.M.Surhone. 2010, Betascript Pub., ISBN: 978-6133459274

PHYSICS-DSE-I: EXPERIMENTAL TECHNIQUES
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Measurements: Accuracy and precision. Significant figures. Error and uncertainty analysis. Types of errors: Gross error, systematic error, random error. Statistical analysis of data (Arithmetic mean, deviation from mean, average deviation, standard deviation, chi-square) and curve fitting. Guassian distribution. **(7 Lectures)**

Signals and Systems: Periodic and aperiodic signals. Impulse response, transfer functionand frequency response of first and second order systems. Fluctuations and Noise in measurement system. S/N ratio and Noise figure. Noise in frequency domain. Sources of Noise: Inherent fluctuations, Thermal noise, Shot noise, 1/f noise. **(7 Lectures)**

Shielding and Grounding: Methods of safety grounding. Energy coupling. Grounding. Shielding: Electrostatic shielding. Electromagnetic Interference. **(4 Lectures)**

Transducers & industrial instrumentation (working principle, efficiency, applications): Static and dynamic characteristics of measurement Systems. Generalized performance of systems, Zero order first order, second order and higher order systems. Electrical, Thermal and Mechanical systems. Calibration. Transducers and sensors. Characteristics of Transducers. Transducers as electrical element and their signal conditioning. Temperature transducers: RTD, Thermistor, Thermocouples, Semiconductor type temperature sensors (AD590, LM35, LM75) and signal conditioning. Linear Position transducer: Strain gauge, Piezoelectric. Inductance change transducer: Linear variable differential transformer (LVDT), Capacitance change transducers. Radiation Sensors: Principle of Gas filleddetector, ionization chamber, scintillation detector. **(21 Lectures)**

Digital Multimeter: Comparison of analog and digital instruments. Block diagram ofdigital multimeter, principle of measurement of I, V, C. Accuracy and resolution of measurement. **(5 Lectures)**

Impedance Bridges and Q-meter: Block diagram and working principles of RLC bridge.
Q-meter and its working operation. Digital LCR bridge. **(4 Lectures)**

Vacuum Systems: Characteristics of vacuum: Gas law, Mean free path. Application ofvacuum. Vacuum system- Chamber, Mechanical pumps, Diffusion pump & Turbo Modular pump, Pumping speed, Pressure gauges (Pirani, Penning, ionization). **(12 Lectures)**

Reference Books:

- Measurement, Instrumentation and Experiment Design in Physics and Engineering, M. Sayer and A. Mansingh, PHI Learning Pvt. Ltd.
- Experimental Methods for Engineers, J.P. Holman, McGraw Hill
- Introduction to Measurements and Instrumentation, A.K. Ghosh, 3rd Edition, PHI Learning Pvt. Ltd.
- Transducers and Instrumentation, D.V.S. Murty, 2nd Edition, PHI Learning Pvt. Ltd.

- Instrumentation Devices and Systems, C.S. Rangan, G.R. Sarma, V.S.V. Mani, Tata McGraw Hill
- Principles of Electronic Instrumentation, D. Patranabis, PHI Learning Pvt. Ltd.
- Electronic circuits: Handbook of design & applications, U.Tietze, Ch.Schenk, Springer

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PRACTICAL- DSE-I LAB: EXPERIMENTAL TECHNIQUES

60 Lectures

1. Determine output characteristics of a LVDT & measure displacement using LVDT
2. Measurement of Strain using Strain Gauge.
3. Measurement of level using capacitive transducer.
4. To study the characteristics of a Thermostat and determine its parameters.
5. Study of distance measurement using ultrasonic transducer.
6. Calibrate Semiconductor type temperature sensor (AD590, LM35, or LM75)
7. To measure the change in temperature of ambient using Resistance Temperature Device (RTD).
8. Create vacuum in a small chamber using a mechanical (rotary) pump and measure the chamber pressure using a pressure gauge.
9. Comparison of pickup of noise in cables of different types (co-axial, single shielded, double shielded, without shielding) of 2m length, understanding of importance of grounding using function generator of mV level & an oscilloscope.
10. To design and study the Sample and Hold Circuit.
11. Design and analyze the Clippers and Clampers circuits using junction diode
12. To plot the frequency response of a microphone.
13. To measure Q of a coil and influence of frequency, using a Q-meter.

Reference Books:

- Electronic circuits: Handbook of design and applications, U. Tietze and C. Schenk, 2008, Springer
- Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1990, Mc-Graw Hill

- Measurement, Instrumentation and Experiment Design in Physics & Engineering, M. Sayer and A. Mansingh, 2005, PHI Learning.

PHYSICS-DSE-II: EMBEDDED SYSTEM: INTRODUCTION TO MICROCONTROLLERS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Embedded system introduction: Introduction to embedded systems and generalpurpose computer systems, architecture of embedded system, classifications, applications and purpose of embedded systems, challenges & design issues in embedded systems, operational and non-operational quality attributes of embedded systems, elemental description of embedded processors and microcontrollers. **(4 Lectures)**

Review of microprocessors: Organization of Microprocessor based system, 8085μp pindiagram and architecture, concept of data bus and address bus, 8085 programming model, instruction classification, subroutines, stacks and its implementation, delay subroutines, hardware and software interrupts. **(4 Lectures)**

8051 microcontroller: Introduction and block diagram of 8051 microcontroller,architecture of 8051, overview of 8051 family, 8051 assembly language programming, Program Counter and ROM memory map, Data types and directives, Flag bits and Program Status Word (PSW) register, Jump, loop and call instructions. **(12 Lectures)**

8051 I/O port programming: Introduction of I/O port programming, pin out diagram of8051 microcontroller, I/O port pins description & their functions, I/O port programming in 8051 (using assembly language), I/O programming: Bit manipulation. **(4 Lectures)**

Programming: 8051 addressing modes and accessing memory using various addressing modes, assembly language instructions using each addressing mode, arithmetic and logic instructions, 8051 programming in C: for time delay & I/O operations and manipulation, for arithmetic and logic operations, for ASCII and BCD conversions. **(12 Lectures)**

Timer and counter programming: Programming 8051 timers, counter programming.

(3 Lectures)

Serial port programming with and without interrupt: Introduction to 8051 interrupts, programming timer interrupts, programming external hardware interrupts and serial communication interrupt, interrupt priority in the 8051. **(6 Lectures)**

Interfacing 8051 microcontroller to peripherals: Parallel and serial ADC, DAC interfacing, LCD interfacing. **(2 Lectures)**

Programming Embedded Systems: Structure of embedded program, infinite loop, compiling, linking and locating, downloading and debugging. **(3 Lectures)**

Embedded system design and development: Embedded system development environment, file types generated after cross compilation, disassembler/ decompiler, simulator, emulator and debugging, embedded product development life-cycle, trends in embedded industry.

(8 Lectures)

Introduction to Arduino: Pin diagram and description of Arduino UNO. Basic programming.

(2 Lectures)

Reference Books:

- Embedded Systems: Architecture, Programming & Design, R.Kamal, 2008,Tata McGraw Hill
- The 8051 Microcontroller and Embedded Systems Using Assembly and C, M.A. Mazidi, J.G. Mazidi, and R.D. McKinlay, 2nd Ed., 2007, Pearson Education India.
- Embedded microcomputor system: Real time interfacing, J.W.Valvano, 2000, Brooks/Cole
- Microcontrollers in practice, I. Susnea and M. Mitescu, 2005, Springer.
- Embedded Systems: Design & applications, S.F. Barrett, 2008, Pearson Education India
- Embedded Microcomputer systems: Real time interfacing, J.W. Valvano 2011, C engage Learning

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PRACTICALS- DSE-II LAB: EMBEDDED SYSTEM: INTRODUCTION TO MICROCONTROLLERS

60 Lectures

8051 microcontroller based Programs and experiments

1. To find that the given numbers is prime or not.
2. To find the factorial of a number.
3. Write a program to make the two numbers equal by increasing the smallest number and decreasing the largest number.
4. Use one of the four ports of 8051 for O/P interfaced to eight LED's. Simulate binary counter (8 bit) on LED's .
5. Program to glow the first four LEDs then next four using TIMER application.
6. Program to rotate the contents of the accumulator first right and then left.
7. Program to run a countdown from 9-0 in the seven segment LED display.
8. To interface seven segment LED display with 8051 microcontroller and display 'HELP' in the seven segment LED display.
9. To toggle '1234' as '1324' in the seven segment LED display.
10. Interface stepper motor with 8051 and write a program to move the motor through a given angle in clock wise or counter clockwise direction.
11. Application of embedded systems: Temperature measurement, some information on LCD display, interfacing a keyboard.

Arduino based programs and experiments:

12. Make a LED flash at different time intervals.
13. To vary the intensity of LED connected to Arduino
14. To control speed of a stepper motor using a potential meter connected to Arduino
15. To display "PHYSICS" on LCD/CRO.

Reference Books:

- Embedded Systems: Architecture, Programming& Design, R.Kamal,]2008,Tata McGraw Hill
- The 8051 Microcontroller and Embedded Systems Using Assembly and C, M.A. Mazidi, J.G. Mazidi, and R.D. McKinlay, 2nd Ed., 2007, Pearson Education India.

- Embedded Microcomputor System: Real Time Interfacing, J.W.Valvano, 2000, Brooks/Cole
- Embedded System, B.K. Rao, 2011, PHI Learning Pvt. Ltd.
- Embedded Microcomputer systems: Real time interfacing, J.W. Valvano 2011,Cengage Learning

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PHYSICS-DSE-III: PHYSICS OF DEVICES AND INSTRUMENTS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Devices: Characteristic and small signal equivalent circuits of UJT and JFET. Metal-semiconductor Junction. Metal oxide semiconductor (MOS) device. Ideal MOS and Flat Band voltage. SiO2-Si based MOS. MOSFET– their frequency limits. Enhancement and Depletion Mode MOSFETS, CMOS. Charge coupled devices. Tunnel diode. **(14 Lectures)**

Power supply and Filters: Block Diagram of a Power Supply, Qualitative idea of C and L Filters. IC Regulators, Line and load regulation, Short circuit protection **(3 Lectures)**

Active and Passive Filters, Low Pass, High Pass, Band Pass and band Reject Filters.
(3 Lectures)

Multivibrators: Astable and Monostable Multivibrators using transistors. **(3 Lectures)**

Phase Locked Loop(PLL): Basic Principles, Phase detector(XOR & edge triggered), Voltage Controlled Oscillator (Basics, varactor). Loop Filter– Function, Loop Filter Circuits, transient response, lock and capture. Basic idea of PLL IC (565 or 4046). **(5 Lectures)**

Processing of Devices: Basic process flow for IC fabrication, Electronic grade silicon.Crystal plane and orientation. Defects in the lattice. Oxide layer. Oxidation Technique for Si. Metallization technique. Positive and Negative Masks. Optical lithography. Electron lithography. Feature size control and wet anisotropic etching. Lift off Technique. Diffusion and implantation. **(12 Lectures)**

Digital Data Communication Standards: Serial Communications: RS232, Handshaking, Implementation of RS232 on PC. Universal Serial Bus (USB): USB standards, Types and elements of USB transfers. Devices (Basic idea of UART). Parallel Communications: General Purpose Interface Bus (GPIB), GPIB signals and lines, Handshaking and interface management, Implementation of a GPIB on a PC. Basic idea of sending data through a COM port.**(5 Lectures)**

Introduction to communication systems: Block diagram of electronic communication system, Need for modulation. Amplitude modulation. Modulation Index. Analysis of Amplitude Modulated wave. Sideband frequencies in AM wave. CE Amplitude Modulator. Demodulation of AM wave using Diode Detector. basic idea of Frequency, Phase, Pulse and Digital Modulation including ASK, PSK, FSK. **(15 lectures)**

Reference Books:

- Physics of Semiconductor Devices, S.M. Sze & K.K. Ng, 3rd Ed.2008, John Wiley & Sons
- Electronic devices and integrated circuits, A.K. Singh, 2011, PHI Learning Pvt. Ltd.
- Op-Amps & Linear Integrated Circuits, R.A.Gayakwad,4 Ed. 2000,PHI Learning Pvt. Ltd
- Electronic Devices and Circuits, A. Mottershead, 1998, PHI Learning Pvt. Ltd.
- Electronic Communication systems, G. Kennedy, 1999, Tata McGraw Hill.
- Introduction to Measurements & Instrumentation, A.K. Ghosh, 3rd Ed., 2009, PHI Learning Pvt. Ltd.
- Semiconductor Physics and Devices, D.A. Neamen, 2011, 4th Edition, McGraw Hill
- PC based instrumentation; Concepts & Practice, N.Mathivanan, 2007, Prentice-Hall of India

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PRACTICAL- DSE-III LAB: PHYSICS OF DEVICES AND INSTRUMENTS 60 Lectures

Experiments from both Section A and Section B:

Section-A

1. To design a power supply using bridge rectifier and study effect of C-filter.
2. To design the active Low pass and High pass filters of given specification.
3. To design the active filter (wide band pass and band reject) of given specification.
4. To study the output and transfer characteristics of a JFET.
5. To design a common source JFET Amplifier and study its frequency response.
6. To study the output characteristics of a MOSFE

7. To study the characteristics of a UJT and design a simple Relaxation Oscillator.
8. To design an Amplitude Modulator using Transistor.
9. To design PWM, PPM, PAM and Pulse code modulation using ICs.
10. To design an Astable multivibrator of given specifications using transistor.
11. To study a PLL IC (Lock and capture range).
12. To study envelope detector for demodulation of AM signal.
13. Study of ASK and FSK modulator.
14. Glow an LED via USB port of PC.
15. Sense the input voltage at a pin of USB port and subsequently glow the LED connected with another pin of USB port.

Section-B:
SPICE/MULTISIM simulations for electrical networks and electronic circuits

1. To verify the Thevenin and Norton Theorems.
2. Design and analyze the series and parallel LCR circuits
3. Design the inverting and non-inverting amplifier using an Op-Amp of given gain
4. Design and Verification of op-amp as integrator and differentiator
5. Design the 1st order active low pass and high pass filters of given cutoff frequency
6. Design a Wein`s Bridge oscillator of given frequency.
7. Design clocked SR and JK Flip-Flop`s using NAND Gates
8. Design 4-bit asynchronous counter using Flip-Flop ICs
9. Design the CE amplifier of a given gain and its frequency response.
10. Design an Astable multivibrator using IC555 of given duty cycle.

Reference Books:

- Basic Electronics:A text lab manual, P.B. Zbar, A.P. Malvino, M.A.Miller,1994, Mc-Graw Hill
- Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
- Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
- OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edn., 2000, Prentice Hall.
- Introduction to PSPICE using ORCAD for circuits & Electronics, M.H. Rashid, 2003, PHI Learning.

- PC based instrumentation; Concepts & Practice, N.Mathivanan, 2007, Prentice-Hall of India

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PHYSICS-DSE-IV: ADVANCED MATHEMATICAL PHYSICS-I
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.

Linear Vector Spaces: Abstract Systems. Binary Operations and Relations. Introduction to Groups and Fields. Vector Spaces and Subspaces. Linear Independence and Dependence of Vectors. Basis and Dimensions of a Vector Space. Change of basis. Homomorphism and Isomorphism of Vector Spaces. Linear Transformations. Algebra of Linear Transformations. Non-singular Transformations. Representation of Linear Transformations by Matrices. **(12 Lectures)**

Matrices: Addition and Multiplication of Matrices. Null Matrices. Diagonal, Scalar and Unit Matrices. Upper-Triangular and Lower-Triangular Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices. Conjugate of a Matrix. Hermitian and Skew-Hermitian Matrices. Singular and Non-Singular matrices. Orthogonal and Unitary Matrix. Trace of a Matrix. Inner Product. **(8 Lectures)**

Eigen-values and Eigenvectors. Cayley- Hamiliton Theorem. Diagonalization of Matrices. Solution of Coupled Linear Ordinary Differential Equations.
Functions of a Matrix **(10 Lectures)**

Cartesian Tensors: Transformation of Co-ordinates. Einstein's Summation Convention. Relation between Direction Cosines. Tensors. Algebra of Tensors. Sum, Difference and Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti-symmetric Tensors. Invariant Tensors : Kronecker and Alternating Tensors. Association of Antisymmetric Tensor of Order Two and Vectors. Vector Algebra and Calculus using Cartesian Tensors : Scalar and Vector Products, Scalar and Vector Triple Products. Differentiation. Gradient, Divergence and Curl of Tensor Fields. Vector Identities. Tensorial Formulation of Analytical Solid Geometry :

Equation of a Line. Angle Between Lines. Projection of a Line on another Line. Condition for Two Lines to be Coplanar. Foot of the Perpendicular from a Point on a Line. Rotation Tensor (No Derivation). Isotropic Tensors. Tensorial Character of Physical Quantities. Moment of Inertia Tensor. Stress and Strain Tensors : Symmetric Nature. Elasticity Tensor. Generalized Hooke's Law. **(20 lectures)**

General Tensors: Transformation of Co-ordinates. Minkowski Space. Contravariant & Covariant Vectors. Contravariant, Covariant and Mixed Tensors. Kronecker Delta and Permutation Tensors. Algebra of Tensors. Sum, Difference & Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti-symmetric Tensors. Metric Tensor. **(10 Lectures)**

Reference Books:

- Mathematical Tools for Physics, James Nearing, 2010, Dover Publications
- Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, and F.E. Harris, 1970, Elsevier.
- Modern Mathematical Methods for Physicists and Engineers, C.D. Cantrell, 2011, Cambridge University Press
- Introduction to Matrices and Linear Transformations, D.T. Finkbeiner, 1978, Dover Pub.
- Linear Algebra, W. Cheney, E.W.Cheney & D.R.Kincaid, 2012, Jones & Bartlett Learning

- Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole
- Mathematical Methods for Physicis & Engineers, K.F.Riley, M.P.Hobson, S.J.Bence,
- 3rd Ed., 2006, Cambridge University Press

PHYSICS PRACTICAL-DSE-IV LAB: ADVANCED MATHEMATICAL PHYSICS-I

60 Lectures

Scilab/ C++ based simulations experiments based on Mathematical Physics problems like

1. Linear algebra:
   - Multiplication of two 3 x 3 matrices.

- Eigenvalue and eigenvectors of

$$\begin{pmatrix} 2 & 1 & 1 \\ 1 & 3 & 2 \\ 3 & 1 & 4 \end{pmatrix};\ \begin{pmatrix} 1 & -i & 3+4i \\ +i & 2 & 4 \\ 3-4i & 4 & 3 \end{pmatrix};\ \begin{pmatrix} 2 & -i & 2i \\ +i & 4 & 3 \\ -2i & 3 & 5 \end{pmatrix}$$

2. Orthogonal polynomials as eigenfunctions of Hermitian differential operators.
3. Determination of the principal axes of moment of inertia through diagonalization.
4. Vector space of wave functions in Quantum Mechanics: Position and momentum differential operators and their commutator, wave functions for stationary states as eigenfunctions of Hermitian differential operator.
5. Lagrangian formulation in Classical Mechanics with constraints.
6. Study of geodesics in Euclidean and other spaces (surface of a sphere, etc).
7. Estimation of ground state energy and wave function of a quantum system.

Reference Books:

- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896
- Scilab by example: M. Affouf, 2012, ISBN: 978-1479203444
- Scilab Image Processing: L.M.Surhone. 2010, Betascript Pub., ISBN: 978-6133459274

PHYSICS-DSE-V: Advanced Mathematical Physics –II
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

Calculus of Variations: Variable Calculus: Variational Principle, Euler's Equation and its Application to Simple Problems. Geodesics. Concept of Lagrangian. Generalized co-ordinates. Definition of canonical moment, Euler-Lagrange's Equations of Motion and its Applications to Simple Problems (e.g., Simple Pendulum and One dimensional harmonic oscillator). Definition of Canonical Momenta. Canonical Pair of Variables. Definition of Generalized Force: Definition of Hamiltonian (Legendre Transformation). Hamilton's Principle. Poisson Brackets and their properties. Lagrange Brackets and their properties. **(25 Lectures)**

Group Theory: Review of sets, Mapping and Binary Operations, Relation, Types of Relations. Groups: Elementary properties of groups, uniqueness of solution, Subgroup, Centre of a group, Co-sets of a subgroup, cyclic group, Permutation/Transformation. Homomorphism and Isomorphism of group. Normal and conjugate subgroups, Completeness and Kernel. Some special groups with operators. Matrix Representations: Reducible and Irreducible **(25 Lectures)**

Advanced Probability Theory: Fundamental Probability Theorems. Conditional Probability, Bayes' Theorem, Repeated Trials, Binomial and Multinomial expansions. Random Variables and probability distributions, Expectation and Variance, Special Probability distributions: The binomial distribution, The poisson distribution, Continuous distribution: The Gaussian (or normal) distribution, The principle of least squares. **(25 Lectures)**

Reference Books:

- Mathematical Methods for Physicists: Weber and Arfken, 2005, Academic Press.
- Mathematical Methods for Physicists: A Concise Introduction: Tai L. Chow, 2000, Cambridge Univ. Press.
- Elements of Group Theory for Physicists by A. W. Joshi, 1997, John Wiley.
- Group Theory and its Applications to Physical Problems by Morton Hamermesh, 1989, Dover
- Introduction to Mathematical Physics: Methods & Concepts: Chun Wa Wong, 2012, Oxford University Press

- Introduction to Mathematical Probability, J. V. Uspensky, 1937, Mc Graw-Hill.

PHYSICS-DSE-VI: CLASSICAL DYNAMICS
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.

Classical Mechanics of Point Particles: Review of Newtonian Mechanics; Applicationto the motion of a charge particle in external electric and magnetic fields- motion in uniform electric field, magnetic field- gyroradius and gyrofrequency, motion in crossed electric and magnetic fields. Generalized coordinates and velocities, Hamilton's principle, Lagrangian and the Euler-Lagrange equations, one-dimensional examples of the Euler-Lagrange equations- one-dimensional Simple Harmonic Oscillations and falling body in uniform gravity; applications to simple systems such as coupled oscillators Canonical momenta & Hamiltonian. Hamilton's equations of motion.

Applications: Hamiltonian for a harmonic oscillator, solution of Hamilton's equation for Simple Harmonic Oscillations; particle in a central force field- conservation of angular momentum and energy. **(22 Lectures)**

Small Amplitude Oscillations: Minima of potential energy and points of stable equilibrium, expansion of the potential energy around a minimum, small amplitude oscillations about the minimum, normal modes of oscillations example of N identical masses connected in a linear fashion to (N -1) - identical springs. **(10 Lectures)**

Special Theory of Relativity: Postulates of Special Theory of Relativity. Lorentz Transformations. Minkowski space. The invariant interval, light cone and world lines. Space-time diagrams. Time -dilation, length contraction and twin paradox. Four-vectors: space-like, time-like and light-like. Four-velocity and acceleration. Metric and alternating tensors. Four-momentum and energy-momentum relation. Doppler effect from a four-vector perspective. Concept of four-force. Conservation of four-momentum. Relativistic kinematics. Application to two-body decay of an unstable particle. **(33 Lectures)**

Fluid Dynamics: Density and pressure P in a fluid, an element of fluid and its velocity, continuity equation and mass conservation, stream-lined motion, laminar flow, Poiseuille's equation for flow of a liquid through a pipe, Navier-Stokes equation, qualitative description of turbulence, Reynolds number. **(10 Lectures)**

Reference Books:

- Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rd Edn. 2002,Pearson Education.
- Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
- Classical Electrodynamics, J.D. Jackson, 3rd Edn., 1998, Wiley.
- The Classical Theory of Fields, L.D Landau, E.M Lifshitz, 4th Edn., 2003, Elsevier.
- Introduction to Electrodynamics, D.J. Griffiths, 2012, Pearson Education.
- Classical Mechanics, P.S. Joag, N.C. Rana, 1st Edn., McGraw Hall.
- Classical Mechanics, R. Douglas Gregory, 2015, Cambridge University Press.
- Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer.
- Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press

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PHYSICS-DSE-VII: APPLIED DYNAMICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Introduction to Dynamical systems: Definition of a continuous first order dynamicalsystem. The idea of phase space, flows and trajectories. Simple mechanical systems as first order dynamical systems : the free particle, particle under uniform gravity, simple and damped harmonic oscillator. Sketching flows and trajectories in phase space; sketching variables as functions of time, relating the equations and pictures to the underlying physical intuition.

Other examples of dynamical systems –

In Biology: Population models e.g. exponential growth and decay, logistic growth, species competition, predator-prey dynamics, simple genetic circuits

In Chemistry: Rate equations for chemical reactions e.g. auto catalysis, bistability

In Economics: Examples from game theory.

Illustrative examples from other disciplines.

Fixed points, attractors, stability of fixed points, basin of attraction, notion of qualitative analysis of dynamical systems, with applications to the above examples.

Computing and visualizing trajectories on the computer using software packages.

Discrete dynamical systems. The logistic map as an example. **(26 Lectures)**

Introduction to Chaos and Fractals: Examples of 2-dimensional billiard, Projection ofthe trajectory on momentum space. Sinai Billiard and its variants. Computational visualization of trajectories in the Sinai Billiard. Randomization and ergodicity in the divergence of nearby phase space trajectories, and dependence of time scale of divergence on the size of obstacle. Electron motion in mesoscopic conductors as a chaotic billiard problem. Other examples of chaotic systems; visualization of their trajectories on the computer.

Self similarity and fractal geometry: Fractals in nature – trees, coastlines, earthquakes, etc. Need for fractal dimension to describe self-similar structure. Deterministic fractal vs. self-similar fractal structure. Fractals in dynamics – Serpinski gasket and DLA.

Chaos in nonlinear finite-difference equations- Logistic map: Dynamics from time series. Parameter dependence- steady, periodic and chaos states. Cobweb iteration. Fixed points. Defining chaos- aperiodic, bounded, deterministic and sensitive dependence on initial conditions. Period- Doubling route to chaos.

Nonlinear time series analysis and chaos characterization: Detecting chaos from return map. Power spectrum, autocorrelation, Lyapunov exponent, correlation dimension. **(20 Lectures)**

Elementary Fluid Dynamics: Importance of fluids: Fluids in the pure sciences, Fluids in technology. Study of fluids: Theoretical approach, experimental fluid dynamics, computational fluid dynamics. Basic physics of fluids: The continuum hypothesis-concept of fluid element or fluid parcel; Definition of a fluid- shear stress; Fluid properties- viscosity, thermal conductivity, mass diffusivity, other fluid properties and equation of state; Flow phenomena- flow dimensionality, steady and unsteady flows, uniform & non-uniform flows, viscous & inviscid flows, incompressible & compressible flows, laminar and turbulent flows, rotational and irrotational flows, separated & unseparated flows. Flow visualization - streamlines, pathlines, Streaklines. **(14 Lectures)**

Reference Books

- Nonlinear Dynamics and Chaos, S.H. Strogatz, Levant Books, Kolkata, 2007
- Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
- An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002
- Fluid Mechanics, 2nd Edition, L. D. Landau and E. M. Lifshitz, Pergamon Press, Oxford, 1987.

PHYSICS PRACTICAL-DSE-VII LAB: APPLIED DYNAMICS 60 Lectures

Laboratory/Computing and visualizing trajectories using software such as Scilab, Maple, Octave, XPPAUT based on Applied Dynamics problems like

1. To determine the coupling coefficient of coupled pendulums.
2. To determine the coupling coefficient of coupled oscillators.
3. To determine the coupling and damping coefficient of damped coupled oscillator.
4. To study population models e.g. exponential growth and decay, logistic growth, species competition, predator-prey dynamics, simple genetic circuits.
5. To study rate equations for chemical reactions e.g. auto catalysis, bistability.
6. To study examples from game theory.
7. Computational visualization of trajectories in the Sinai Billiard.
8. Computational visualization of trajectories Electron motion in mesoscopic conductors as a chaotic billiard problem.
9. Computational visualization of fractal formations of Deterministic fractal.
10. Computational visualization of fractal formations of self-similar fractal.
11. Computational visualization of fractal formations of Fractals in nature – trees, coastlines, earthquakes.
12. Computational Flow visualization - streamlines, pathlines, Streaklines.

Reference Books:

- Nonlinear Dynamics and Chaos, Steven H. Strogatz, Levant Books, Kolkata, 2007
- Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
- An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002
- Fluid Mechanics, 2nd Edn, L.D.Landau & E.M. Lifshitz, Pergamon Press, Oxford, 1987

- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896
- Scilab by example: M. Affouf, 2012, ISBN: 978-1479203444
- Scilab Image Processing: L.M.Surhone. 2010, Betascript Pub., ISBN: 978-6133459274

PHYSICS- DSE-VIII: COMMUNICATION ELECTRONICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Electronic communication: Introduction to communication – means and modes. Need for modulation. Block diagram of an electronic communication system. Brief idea of frequency allocation for radio communication system in India (TRAI). Electromagnetic communication spectrum, band designations and usage. Channels and base-band signals. Concept of Noise, signal-to-noise (S/N) ratio. **(8 Lectures)**

Analog Modulation: Amplitude Modulation, modulation index and frequency spectrum.Generation of AM (Emitter Modulation), Amplitude Demodulation (diode detector), Concept of Single side band generation and detection. Frequency Modulation (FM) and Phase Modulation (PM), modulation index and frequency spectrum, equivalence between FM and PM, Generation of FM using VCO, FM detector (slope detector), Qualitative idea of Super heterodyne receiver **(12 Lectures)**

Analog Pulse Modulation: Channel capacity, Sampling theorem, Basic Principles-PAM, PWM, PPM, modulation and detection technique for PAM only, Multiplexing. **(9 Lectures)**

Digital Pulse Modulation: Need for digital transmission, Pulse Code Modulation, Digital Carrier Modulation Techniques, Sampling, Quantization and Encoding. Concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Binary Phase Shift Keying (BPSK). **(10 Lectures)**

Introduction to Communication and Navigation systems:

Satellite Communication– Introduction, need, Geosynchronous satellite orbits, geostationary satellite advantages of geostationary satellites. Satellite visibility, transponders (C - Band), path loss, ground station, simplified block diagram of earth station. Uplink and downlink. **(10 Lectures)**

Mobile Telephony System – Basic concept of mobile communication, frequency bandsused in mobile communication, concept of cell sectoring and cell splitting, SIM number, IMEI number, need for data encryption, architecture (block diagram) of mobile communication network, idea of GSM, CDMA, TDMA and FDMA technologies, simplified block diagram of mobile phone handset, 2G, 3G and 4G concepts (qualitative only). **(10 Lectures)**

GPS navigation system (qualitative idea only) **(1 Lecture)**

Reference Books:

- Electronic Communications, D. Roddy and J. Coolen, Pearson Education India.
- Advanced Electronics Communication Systems- Tomasi, 6th edition, Prentice Hall.
- Electronic Communication systems, G. Kennedy, 3rd Edn., 1999, Tata McGraw Hill.
- Principles of Electronic communication systems – Frenzel, 3rd edition, McGraw Hill
- Communication Systems, S. Haykin, 2006, Wiley India
- Electronic Communication system, Blake, Cengage, 5th edition.
- Wireless communications, Andrea Goldsmith, 2015, Cambridge University Press

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PHYSICS PRACTICAL-DSE-VIII LAB: COMMUNICATION ELECTRONICS LAB
60 Lectures

1. To design an Amplitude Modulator using Transistor
2. To study envelope detector for demodulation of AM signal
3. To study FM - Generator and Detector circuit
4. To study AM Transmitter and Receiver
5. To study FM Transmitter and Receiver
6. To study Time Division Multiplexing (TDM)

7. To study Pulse Amplitude Modulation (PAM)
8. To study Pulse Width Modulation (PWM)
9. To study Pulse Position Modulation (PPM)
10. To study ASK, PSK and FSK modulators

Reference Books:

- Electronic Communication systems, G. Kennedy, 1999, Tata McGraw Hill.
- Electronic Communication system, Blake, Cengage, 5^{th} edition.

PHYSICS-DSE-IX: Nuclear and Particle Physics
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states. **(10 Lectures)**

Nuclear Models: Liquid drop model approach, semi empirical mass formula andsignificance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force. **(12 Lectures)**

Radioactivity decay: (a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) □-decay: energy kinematics for □-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion. **(10 Lectures)**

Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering). **(8 Lectures)**

Interaction of Nuclear Radiation with matter: Energy loss due to ionization (Bethe-Block formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter. **(8 Lectures)**

Detector for Nuclear Radiations: Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector. **(8 Lectures)**

Particle Accelerators: Accelerator facility available in India: Van-de Graaff Generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons. **(5 Lectures)**

Particle physics: Particle interactions; basic features, types of particles and its families.Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quarkmodel, color quantum number and gluons. **(14 Lectures)**

Reference Books:

- Introductory nuclear Physics by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
- Concepts of nuclear physics by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).
- Introduction to the physics of nuclei & particles, R.A. Dunlap. (Thomson Asia, 2004).
- Introduction to High Energy Physics, D.H. Perkins, Cambridge Univ. Press
- Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
- Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi
- Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde (IOP-Institute of Physics Publishing, 2004).
- Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
- Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (Academic Press, Elsevier, 2007).
- Theoretical Nuclear Physics, J.M. Blatt & V.F.Weisskopf (Dover Pub.Inc., 1991)

PHYSICS-DSE-X: Astronomy & Astrophysics
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

Astronomical Scales: Astronomical Distance, Mass and Time, Scales, Brightness,Radiant Flux and Luminosity, Measurement of Astronomical Quantities Astronomical Distances, Stellar Radii, Masses of Stars, Stellar Temperature. **Basic concepts of positional astronomy:** Celestial Sphere, Geometry of a Sphere, Spherical Triangle, Astronomical Coordinate Systems, Geographical Coordinate Systems, Horizon System, Equatorial System, Diurnal Motion of the Stars, Conversion of Coordinates. Measurement of Time, Sidereal Time, Apparent Solar Time, Mean Solar Time, Equation of Time, Calendar. Basic Parameters of Stars: Determination of Distance by Parallax Method; Brightness, Radiant Flux and Luminosity, Apparent and Absolute magnitude scale, Distance Modulus; Determination of Temperature and Radius of a star; Determination of Masses from Binary orbits; Stellar Spectral Classification, Hertzsprung-Russell Diagram. **(24 Lectures)**

Astronomical techniques: Basic Optical Definitions for Astronomy (MagnificationLight Gathering Power, Resolving Power and Diffraction Limit, Atmospheric Windows), Optical Telescopes (Types of Reflecting Telescopes, Telescope Mountings, Space Telescopes, Detectors and Their Use with Telescopes (Types of Detectors, detection Limits with Telescopes).
Physical principles: Gravitation in Astrophysics (Virial Theorem, Newton versus Einstein), Systems in Thermodynamic Equilibrium. **(9 Lectures)**

The sun (Solar Parameters, Solar Photosphere, Solar Atmosphere, Chromosphere.Corona, Solar Activity, Basics of Solar Magneto-hydrodynamics. Helioseismology). **The solar family** (Solar System: Facts and Figures, Origin of the Solar System: TheNebular Model, Tidal Forces and Planetary Rings, Extra-Solar Planets.
Stellar spectra and classification Structure (Atomic Spectra Revisited, Stellar Spectra,Spectral Types and Their Temperature Dependence, Black Body Approximation, H R Diagram, Luminosity Classification) **(11 Lectures)**

The milky way : Basic Structure and Properties of the Milky Way, Nature of Rotation ofthe Milky Way (Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the

Galaxy and the Dark Matter, Nature of the Spiral Arms), Stars and Star Clusters of the Milky Way, Properties of and around the Galactic Nucleus. **(14 Lectures)**

Galaxies: Galaxy Morphology, Hubble's Classification of Galaxies, Elliptical Galaxies (The Intrinsic Shapes of Elliptical, de Vaucouleurs Law, Stars and Gas). Spiral and Lenticular Galaxies (Bulges, Disks, Galactic Halo) The Milky Way Galaxy, Gas and Dust in the Galaxy, Spiral Arms. **(7 Lectures)**

Large scale structure & expanding universe: Cosmic Distance Ladder (An Example from Terrestrial Physics, Distance Measurement using Cepheid Variables), Hubble's Law (Distance-Velocity Relation), Clusters of Galaxies (Virial theorem and Dark Matter). **(10 Lectures)**

Reference Books:

- Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
- Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th Edition, Saunders College Publishing.
- The physical universe: An introduction to astronomy, F.Shu, Mill Valley: University Science Books.
- Fundamental of Astronomy (Fourth Edition), H. Karttunen et al. Springer
- K.S. Krishnasamy, 'Astro Physics a modern perspective,' Reprint, New Age International (p) Ltd, New Delhi,2002.
- Baidyanath Basu, 'An introduction to Astro physics', Second printing, Prentice -Hall of India Private limited, New Delhi,2001.
- Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.

PHYSICS-DSE-XI: Atmospheric Physics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

General features of Earth's atmosphere: Thermal structure of the Earth'sAtmosphere, Ionosphere, Composition of atmosphere, Hydrostatic equation, Potential temperature, Atmospheric Thermodynamics, Greenhouse effect and effective temperature of Earth, Local winds, monsoons, fogs, clouds, precipitation, Atmospheric boundary layer, Sea breeze and land breeze. Instruments for meteorological observations, including RS/RW, meteorological processes and different systems, fronts, Cyclones and anticyclones, thunderstorms. **(12 Lectures)**

Atmospheric Dynamics: Scale analysis, Fundamental forces, Basic conservationlaws, The Vectorial form of the momentum equation in rotating coordinate system, scale analysis of equation of motion, Applications of the basic equations, Circulations and vorticity, Atmospheric oscillations, Quasi biennial oscillation, annual and semi-annual oscillations, Mesoscale circulations, The general circulations, Tropical dynamics. **(12 Lectures)**

Atmospheric Waves: Surface water waves, wave dispersion, acoustic waves,buoyancy waves, propagation of atmospheric gravity waves (AGWs) in a nonhomogeneous medium, Lamb wave, Rossby waves and its propagation in three dimensions and in sheared flow, wave absorption, non-linear consideration **(12 Lectures)**

Atmospheric Radar and Lidar: Radar equation and return signal, Signal processingand detection, Various type of atmospheric radars, Application of radars to study atmospheric phenomena, Lidar and its applications, Application of Lidar to study atmospheric phenomenon. Data analysis tools and techniques. **(12 Lectures)**

Atmospheric Aerosols: Spectral distribution of the solar radiation, Classification andproperties of aerosols, Production and removal mechanisms, Concentrations and size distribution, Radiative and health effects, Observational techniques for aerosols, Absorption and scattering of solar radiation, Rayleigh scattering and Mie scattering, Bouguert-Lambert law, Principles of radiometry, Optical phenomena in atmosphere, Aerosol studies using Lidars. **(12 Lectures)**

Reference Books:

- Fundamental of Atmospheric Physics – Murry L Salby; Academic Press, Vol 61, 1996
- The Physics of Atmosphere – John T. Houghton; Cambridge University press;3rd edn. 2002.
- An Introduction to dynamic meteorology – James R Holton; Academic Press, 2004
- Radar for meteorological and atmospheric observations – S Fukao and KHamazu, Springer Japan, 2014

PRACTICALS-DSE-XI LAB: Atmospheric Physics
60 Lectures
Scilab/C^{++} based simulations experiments based on Atmospheric Physics problems like

1. Numerical Simulation for atmospheric waves using dispersion relations
   (a) Atmospheric gravity waves (AGW)
   (b) Kelvin waves
   (c) Rossby waves, and mountain waves
2. Offline and online processing of radar data
   (a) VHF radar,
   (b) X-band radar, and
   (c) UHF radar
3. Offline and online processing of LIDAR data
4. Radiosonde data and its interpretation in terms of atmospheric parameters using vertical profiles in different regions of the globe.
5. Handling of satellite data and plotting of atmospheric parameters using radio occultation technique
6. Time series analysis of temperature using long term data over metropolitan cities in India – an approach to understand the climate change

Reference Books:

- Fundamental of Atmospheric Physics – Murry L Salby; Academic Press, Vol 61, 1996
- The Physics of Atmosphere – J.T. Houghton; Cambridge Univ. Press; 3rd edn. 2002.
- An Introduction to dynamic meteorology – James R Holton; Academic Press, 2004
- Radar for meteorological and atmospheric observations – S Fukao and K Hamazu, Springer Japan, 2014

PHYSICS-DSE-XII: Nano Materials and Applications
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

NANOSCALE SYSTEMS: Length scales in physics, Nanostructures: 1D, 2D and 3Dnanostructures (nanodots, thin films, nanowires, nanorods)**,** Band structure and density of states of materials at nanoscale, Size Effects in nano systems, Quantum confinement: Applications of Schrodinger equation- Infinite potential well, potential step, potential box, quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences. **(10 Lectures)**

SYNTHESIS OF NANOSTRUCTURE MATERIALS: Top down and Bottom up approach, Photolithography. Ball milling. Gas phase condensation. Vacuum deposition. Physical vapor deposition (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition. Chemical vapor deposition (CVD). Sol-Gel. Electro deposition. Spray pyrolysis. Hydrothermal synthesis. Preparation through colloidal methods. MBE growth of quantum dots. **(8 Lectures)**

CHARACTERIZATION: X-Ray Diffraction. Optical Microscopy. Scanning Electron Microscopy. Transmission Electron Microscopy. Atomic Force Microscopy. Scanning Tunneling Microscopy. **(8 Lectures)**

OPTICAL PROPERTIES: Coulomb interaction in nanostructures. Concept ofdielectric constant for nanostructures and charging of nanostructure. Quasi-particles and excitons. Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasi-particles and excitons, charging effects. Radiative processes: General formalization-absorption, emission and luminescence. Optical properties of heterostrctures and nanostructures. **(14 Lectures)**

ELECTRON TRANSPORT: Carrier transport in nanostrcutures. Coulomb blockade effect, thermionic emission, tunneling and hoping conductivity. Defects and impurities: Deep level and surface defects. **(6 Lectures)**

APPLICATIONS: Applications of nanoparticles, quantum dots, nanowires and thinfilms for photonic devices (LED, solar cells). Single electron transfer devices (no derivation). CNT based transistors. Nanomaterial Devices: Quantum dots heterostructure lasers, optical switching and optical data storage. Magnetic quantum well; magnetic dots - magnetic data storage. Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS). **(14 Lectures)**

Reference books:

- C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology (Wiley India Pvt. Ltd.).
- S.K. Kulkarni, Nanotechnology: Principles & Practices (Capital Publishing Company)
- K.K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (PHI Learning Private Limited).
- Richard Booker, Earl Boysen, Nanotechnology (John Wiley and Sons).
- M. Hosokawa, K. Nogi, M. Naita, T. Yokoyama, Nanoparticle Technology Handbook (Elsevier, 2007).
- Introduction to Nanoelectronics, V.V. Mitin, V.A. Kochelap and M.A. Stroscio, 2011, Cambridge University Press.
- Bharat Bhushan, Springer Handbook of Nanotechnology (Springer-Verlag, Berlin, 2004).

PRACTICALS-DSE-XII LAB: Nano Materials and Applications
60 Lectures

1. Synthesis of metal nanoparticles by chemical route.
2. Synthesis of semiconductor nanoparticles.
3. Surface Plasmon study of metal nanoparticles by UV-Visible spectrophotometer.
4. XRD pattern of nanomaterials and estimation of particle size.
5. To study the effect of size on color of nanomaterials.
6. To prepare composite of CNTs with other materials.
7. Growth of quantum dots by thermal evaporation.
8. Prepare a disc of ceramic of a compound using ball milling, pressing and sintering, and study its XRD.
9. Fabricate a thin film of nanoparticles by spin coating (or chemical route) and study transmittance spectra in UV-Visible region.
10. Prepare a thin film capacitor and measure capacitance as a function of temperature or frequency.

11. Fabricate a PN diode by diffusing Al over the surface of N-type Si and study its V-I characteristic.

Reference Books:

- C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology (Wiley India Pvt. Ltd.).
- S.K. Kulkarni, Nanotechnology: Principles & Practices (Capital Publishing Company).
- K.K. Chattopadhyay and A.N. Banerjee, Introduction to Nanoscience & Technology (PHI Learning Private Limited).
- Richard Booker, Earl Boysen, Nanotechnology (John Wiley and Sons).

PHYSICS-DSE-XIII: Physics of Earth
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

The Earth and the Universe: **(17 Lectures)**

(a) Origin of universe, creation of elements and earth. A Holistic understanding of our dynamic planet through Astronomy, Geology, Meteorology and Oceanography. Introduction to various branches of Earth Sciences.

(b) General characteristics and origin of the Universe. The Milky Way galaxy, solar system, Earth's orbit and spin, the Moon's orbit and spin. The terrestrial and Jovian planets. Meteorites & Asteroids. Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age.

(c) Energy and particle fluxes incident on the Earth.

(d) The Cosmic Microwave Background.

Structure: **(18 Lectures)**

(a) The Solid Earth: Mass, dimensions, shape and topography, internal structure, magnetic field, geothermal energy. How do we learn about Earth's interior?

(b) The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. River systems.

(c) The Atmosphere: variation of temperature, density and composition with altitude, clouds.

(d) The Cryosphere: Polar caps and ice sheets. Mountain glaciers.

(e) The Biosphere: Plants and animals. Chemical composition, mass. Marine and land organisms.

Dynamical Processes: **(18 Lectures)**

(a) The Solid Earth: Origin of the magnetic field. Source of geothermal energy. Convection in Earth's core and production of its magnetic field. Mechanical layering of the Earth. Introduction to geophysical methods of earth investigations. Concept of plate tectonics; sea-floor spreading and continental drift. Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts. Volcanoes: types products and distribution.

(b) The Hydrosphere: Ocean circulations. Oceanic current system and effect of coriolis forces. Concepts of eustasy, tend – air-sea interaction; wave erosion and beach processes. Tides. Tsunamis.

(c) The Atmosphere: Atmospheric circulation. Weather and climatic changes. Earth's heat budget. Cyclones.

Climate:

i. Earth's temperature and greenhouse effect.
ii. Paleoclimate and recent climate changes.
iii. The Indian monsoon system.

(d) Biosphere: Water cycle, Carbon cycle, Nitrogen cycle, Phosphorous cycle. The role of cycles in maintaining a steady state.

Evolution: **(18 Lectures)**

Nature of stratigraphic records, Standard stratigraphic time scale and introduction to the concept of time in geological studies. Introduction to geochronological methods in their application in geological studies. History of development in concepts of uniformitarianism, catastrophism and neptunism. Law of superposition and faunal succession. Introduction to the geology and geomorphology of Indian subcontinent.

1. Time line of major geological and biological events.
2. Origin of life on Earth.
3. Role of the biosphere in shaping the environment.
4. Future of evolution of the Earth and solar system: Death of the Earth.

Disturbing the Earth – Contemporary dilemmas **(4 Lectures)**

(a) Human population growth.

(b) Atmosphere: Green house gas emissions, climate change, air pollution.

(c) Hydrosphere: Fresh water depletion.

(d) Geosphere: Chemical effluents, nuclear waste.

(e) Biosphere: Biodiversity loss. Deforestation. Robustness and fragility of ecosystems.

Reference Books:

- Planetary Surface Processes, H. Jay Melosh, Cambridge University Press, 2011.
- Consider a Spherical Cow: A course in environmental problem solving, John Harte. University Science Books
- Holme's Principles of Physical Geology. 1992. Chapman & Hall.
- Emiliani, C, 1992. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment. Cambridge University Press.

PHYSICS-DSE-XIV: DIGITAL SIGNAL PROCESSING
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Discrete-Time Signals and Systems: Classification of Signals, Transformations of the Independent Variable, Periodic and Aperiodic Signals, Energy and Power Signals, Even and Odd Signals, Discrete-Time Systems, System Properties. Impulse Response, Convolution Sum; Graphical Method; Analytical Method, Properties of Convolution; Commutative; Associative; Distributive; Shift; Sum Property System Response to Periodic Inputs, Relationship Between LTI System Properties and the Impulse Response; Causality; Stability; Invertibility, Unit Step Response. **(10 Lectures)**

Discrete-Time Fourier Transform: Fourier Transform Representation of AperiodicDiscrete-Time Signals, Periodicity of DTFT, Properties; Linearity; Time Shifting; Frequency Shifting; Differencing in Time Domain; Differentiation in Frequency Domain; Convolution Property. **The*z*-Transform:** Bilateral (Two-Sided) *z*-Transform, Inverse *z*-Transform, Relationship Between *z*-Transform and Discrete-Time Fourier Transform, *z*-plane, Region-of-Convergence; Properties of ROC, Properties; Time Reversal; Differentiation in the *z*-Domain; Power Series

Expansion Method (or Long Division Method); Analysis and Characterization of LTI Systems; Transfer Function and Difference-Equation System. Solving Difference Equations. **(15 Lectures)**

Filter Concepts: Phase Delay and Group delay, Zero-Phase Filter, Linear-Phase Filter, Simple FIR Digital Filters, Simple IIR Digital Filters, All pass Filters, Averaging Filters, Notch Filters. **(5 Lectures)**

Discrete Fourier Transform: Frequency Domain Sampling (Sampling of DTFT), The Discrete Fourier Transform (DFT) and its Inverse, DFT as a Linear transformation, Properties; Periodicity; Linearity; Circular Time Shifting; Circular Frequency Shifting; Circular Time Reversal; Multiplication Property; Parseval's Relation, Linear Convolution Using the DFT (Linear Convolution Using Circular Convolution), Circular Convolution as Linear Convolution with aliasing. **(10 Lectures)**

Fast Fourier Transform: Direct Computation of the DFT, Symmetry and Periodicity Properties of the Twiddle factor (*WN*), Radix-2 FFT Algorithms; Decimation-In-Time (DIT) FFT Algorithm; Decimation-In-Frequency (DIF) FFT Algorithm, Inverse DFT Using FFT Algorithms. **(5 Lectures)**

Realization of Digital Filters: Non Recursive and Recursive Structures, Canonic andNon Canonic Structures, Equivalent Structures (Transposed Structure), FIR Filter structures; Direct-Form; Cascade-Form; Basic structures for IIR systems; Direct-Form I. **Finite Impulse Response Digital Filter:** Advantages and Disadvantages of DigitalFilters, Types of Digital Filters: FIR and IIR Filters; Difference Between FIR and IIR Filters, Desirability of Linear-Phase Filters, Frequency Response of Linear-Phase FIR Filters, Impulse Responses of Ideal Filters, Windowing Method; Rectangular; Triangular; Kaiser Window, FIR Digital Differentiators.
Infinite Impulse Response Digital Filter: Design of IIR Filters from Analog Filters,IIR Filter Design by Approximation of Derivatives, Backward Difference Algorithm, Impulse Invariance Method. **(15 Lectures)**

Reference Books:

- Digital Signal Processing, Tarun Kumar Rawat, 2015, Oxford University Press, India
- Digital Signal Processing, S. K. Mitra, McGraw Hill, India.

- Modern Digital and Analog Communication Systems, B.P. Lathi, 1998, 3rd Edn. Oxford University Press.
- Fundamentals of Digital Signal processing using MATLAB, R.J. Schilling and S.L. Harris, 2005, Cengage Learning.
- Fundamentals of signals and systems, P.D. Cha and J.I. Molinder, 2007, Cambridge University Press.
- Digital Signal Processing Principles Algorithm & Applications, J.G. Proakis andD.G. Manolakis, 2007, 4th Edn., Prentice Hall.

PHYSICS PRACTICAL-DSE-XIVLAB: DIGITAL SIGNAL PROCESSING LAB

60 Lectures

Scilab based simulations experiments based problems like

1. Write a program to generate and plot the following sequences: (a) Unit sample sequence δ(n), (b) unit step sequence *u(n)*, (c) ramp sequence *r(n)*, (d) real valued exponential sequence $x(n) = (0.8)^n u(n)$ for $0 \le n \le 50$.

2. Write a program to compute the convolution sum of a rectangle signal (or gate function) with itself for N = 5

   $$x(n) = rect\left(\frac{n}{2N}\right) = \Pi\left(\frac{n}{2N}\right) = \begin{cases} 1 & -N \le n \le N \\ 0 & otherwise \end{cases}$$

3. An LTI system is specified by the difference equation
   $y(n) = 0.8y(n - 1) + x(n)$
   (a) Determine $H(e^{jw})$
   (b) Calculate and plot the steady state response $y_{ss}(n)$ to $x(n) = cos(0.5\pi n)\, u(n)$

4. Given a casual system

   $y(n) = 0.9y(n - 1) + x(n)$
   (a) Find *H(z)* and sketch its pole-zero plot
   (b) Plot the frequency response $|H(e^{jw})|$ and $H(e^{jw})$

5. Design a digital filter to eliminate the lower frequency sinusoid of $x(t) = sin\ 7t + sin\ 200t$. The sampling frequency is $f_s = 500$ Hz. Plot its pole zero diagram, magnitude response, input and output of the filter.

6. Let *x(n)* be a 4-point sequence:
   $$x(n) = \underset{\uparrow}{\{1,1,1,1\}} = \begin{cases} 1 & 0 \le n \le 3 \\ 0 & otherwise \end{cases}$$
   Compute the DTFT $X(e^{jw})$ and plot its magnitude
   (a) Compute and plot the 4 point DFT of *x(n)*

(b) Compute and plot the 8 point DFT of *x(n)* (by appending 4 zeros)
(c) Compute and plot the 16 point DFT of *x(n)* (by appending 12 zeros)

7. Let *x(n)* and *h(n)* be the two 4-point sequences,
   $x(n) = \underset{\uparrow}{\{1,2,2,1\}}$
   $h(n) = \underset{\uparrow}{\{1,-1,-1,1\}}$
   Write a program to compute their linear convolution using circular convolution.

8. Using a rectangular window, design a FIR low-pass filter with a pass-band gain of unity, cut off frequency of 1000 Hz and working at a sampling frequency of 5 KHz. Take the length of the impulse response as 17.

9. Design an FIR filter to meet the following specifications:
   passband edge F_p = 2 KHz
   stopband edge F_s = 5 Khz
   Passband attenuation A_p = 2 dB
   Stopband attenuation A_s = 42 dB
   Sampling frequency F_s = 20 KHz

10. The frequency response of a linear phase digital differentiator is given by

    $H_d(e^{jw}) = jwe^{-j\tau w} \quad |w| \leq \pi$

    Using a Hamming window of length M = 21, design a digital FIR differentiator.

    Plot the amplitude response.

Reference Books:

- Digital Signal Processing, Tarun Kumar Rawat, Oxford University Press, India.
- A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
- Fundamentals of Digital Signal processing using MATLAB, R.J. Schilling and S.L. Harris, 2005, Cengage Learning.
- Digital Signal Processing, S. K. Mitra, McGraw Hill, India.
- Fundamentals of signals and systems, P.D. Cha and J.I. Molinder, 2007, Cambridge University Press.
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896
- Scilab by example: M. Affouf, 2012, ISBN: 978-1479203444

- Scilab Image Processing: L.M.Surhone. 2010, Betascript Pub., ISBN: 978-6133459274

PHYSICS-DSE-XV: Medical Physics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

PHYSICS OF THE BODY-I
Basic Anatomical Terminology: Standard Anatomical Position, Planes. Familiarity with terms like- Superior, Inferior, Anterior, Posterior, Medial, Lateral, Proximal and Distal. **Mechanics of the body:** Skeleton, forces, and body stability. Muscles and dynamics ofbody movement. Physics of Locomotors Systems: joints and movements, Stability and Equilibrium. **Energy household of the body:** Energy balance in the body, Energy consumption of the body, Heat losses of the body, Thermal Regulation. **Pressure system of body:** Physics of breathing, Physics of cardiovascular system. **(8 Lectures)**

PHYSICS OF THE BODY-II
Acoustics of the body: Nature and characteristics of sound, Production of speech, Physics of the ear, Diagnostics with sound and ultrasound. **Optical system of the body:** Physics of the eye. **Electrical system of the body:** Physics of the nervous system, Electrical signals and information transfer. **(10 Lectures)**

PHYSICS OF DIAGNOSTIC AND THERAPEUTIC SYSTEMS-I X-RAYS: Electromagnetic spectrum, production of x-rays, x-ray spectra, Brehmsstrahlung, Characteristic x-ray. **X-ray tubes & types**: Coolidge tube, x-ray tube design, tube cooling stationary mode, Rotating anode x-ray tube, Tube rating, quality and intensity of x-ray. X-ray generator circuits, half wave and full wave rectification, filament circuit, kilo voltage circuit. Single and three phase electric supply. Power ratings. Types of X-Ray Generator, high frequency generator, exposure timers and switches, HT cables. **(7 Lectures)**

RADIATION PHYSICS: Radiation units exposure, absorbed dose, units: rad, gray,relative biological effectiveness, effective dose- Rem & Sievert, inverse square law. Interaction of radiation with matter Compton & photoelectric effect, linear attenuation coefficient. **Radiation**

Detectors: ionization (Thimble chamber, condenser chamber), chamber. Geiger Muller counter, Scintillation counters and Solid State detectors, TFT. **(7 Lectures)**

MEDICAL IMAGING PHYSICS: Evolution of Medical Imaging, X-ray diagnosticsand imaging, Physics of nuclear magnetic resonance (NMR), NMR imaging, MRI Radiological imaging, Ultrasound imaging, Physics of Doppler with applications and modes, Vascular Doppler. Radiography: Filters, grids, cassette, X-ray film, film processing, fluoroscopy. **Computed tomography scanner**- principle and function, display, generations, mammography. Thyroid uptake system and Gamma camera (Only Principle, function and display). **(9 Lectures)**

RADIATION ONCOLOGY PHYSICS: External Beam Therapy (Basic Idea):Telecobalt, Conformal Radiation Therapy (CRT), 3DCRT, IMRT, Image Guided Radiotherapy, EPID, Rapid Arc, Proton Therapy, Gamma Knife, Cyber Knife. Contact Beam Therapy (Basic Idea): Brachytherapy- LDR and HDR, Intra Operative Brachytherapy. Radiotherapy, kilo voltage machines, deep therapy machines, Telecobalt machines, Medical linear accelerator. Basics of Teletherapy units, deep X-ray, Telecobalt units, Radiation protection, external beam characteristics, dose maximum and build up – bolus, percentage depth dose, tissue maximum ratio and tissue phantom ratio, Planned target Volume and Gross Tumour Volume. **(9 Lectures)**

RADIATION AND RADIATION PROTECTION: Principles of radiation protection, protective materials-radiation effects, somatic, genetic stochastic and deterministic effect. Personal monitoring devices: TLD film badge, pocket dosimeter, OSL dosimeter. Radiation dosimeter. Natural radioactivity, Biological effects of radiation, Radiation monitors**.** Steps to reduce radiation to Patient, Staff and Public. Dose Limits for Occupational workers and Public. AERB: Existence and Purpose. **(5 Lectures)**

PHYSICS OF DIAGNOSTIC AND THERAPEUTIC SYSTEMS-II

Diagnostic nuclear medicine: Radiopharmaceuticals for radioisotope imaging, Radioisotope imaging equipment, Single photon and positron emission tomography. Therapeutic nuclear medicine: Interaction between radiation and matter Dose and isodose in radiation treatment. Medical Instrumentation: Basic Ideas of Endoscope and Cautery, Sleep Apnea and Cpap Machines, Ventilator and its modes. **(5 Lectures)**

Reference Books:

- Medical Physics, J.R. Cameron and J.G.Skofronick, Wiley (1978)
- Basic Radiological Physics Dr. K. Thayalan - Jayapee Brothers Medical Publishing Pvt. Ltd. New Delhi (2003)
- Christensen's Physics of Diagnostic Radiology: Curry, Dowdey and Murry - Lippincot Williams and Wilkins (1990)
- Physics of the human body, Irving P. Herman, Springer (2007).
- Physics of Radiation Therapy : F M Khan - Williams and Wilkins, 3rd edition (2003)
- The essential physics of Medical Imaging: Bushberg, Seibert, Leidholdt and Boone Lippincot Williams and Wilkins, Second Edition (2002)
- Handbook of Physics in Diagnostic Imaging: R.S.Livingstone: B.I. Publication Pvt Ltd.
- The Physics of Radiology-H E Johns and Cunningham.

PHYSICS-DSE-XV LAB: Medical Physics
60 Lectures

1. Understanding the working of a manual Hg Blood Pressure monitor and measure the Blood Pressure.
2. Understanding the working of a manual optical eye-testing machine and to learn eye-testing procedure.
3. Correction of Myopia (short sightedness) using a combination of lenses on an optical bench/breadboard.
4. Correction of Hypermetropia/Hyperopia (long sightedness) using a combination of lenses on an optical bench/breadboard.
5. To learn working of Thermoluminescent dosimeter (TLD) badges and measure the background radiation.
6. Familiarization with Geiger-Muller (GM) Counter and to measure background radiation.
7. Familiarization with Radiation meter and to measure background radiation.
8. Familiarization with the Use of a Vascular Doppler.

Reference Books:

- Basic Radiological Physics, Dr. K. Thayalan - Jayapee Brothers Medical Publishing Pvt. Ltd. New Delhi (2003)
- Christensen's Physics of Diagnostic Radiology: Curry, Dowdey and Murry - Lippincot Williams and Wilkins (1990)
- Physics of Radiation Therapy : F M Khan - Williams and Wilkins, 3rd edition (2003)
- The essential physics of Medical Imaging: Bushberg, Seibert, Leidholdt and Boone Lippincot Williams and Wilkins, Second Edition (2002)
- Handbook of Physics in Diagnostic Imaging: Roshan S. Livingstone: B. I. Publications Pvt Ltd.
- The Physics of Radiology-H E Johns and Cunningham.

PHYSICS-DSE-XVI: Biological Physics
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

Overview: **(9 lectures)**

The boundary, interior and exterior environment of living cells. Processes: exchange of matter and energy with environment, metabolism, maintenance, reproduction, evolution. Self-replication as a distinct property of biological systems. Time scales and spatial scales. Universality of microscopic processes and diversity of macroscopic form. Types of cells. Multicellularity. Allometric scaling laws.

Molecules of life: **(22 lectures)**

Metabolites, proteins and nucleic acids. Their sizes, types and roles in structures and processes. Transport, energy storage, membrane formation, catalysis, replication, transcription, translation, signaling.

Typical populations of molecules of various types present in cells, their rates of production and turnover. Energy required to make a bacterial cell.

Simplified mathematical models of transcription and translation, small genetic circuits and signaling pathways. Random walks and applications to biology. Mathematical models to be studied analytically and computationally.

The complexity of life: **(30 lectures)**

At the level of a cell: The numbers of distinct metabolites, genes and proteins in a cell. Complex networks of molecular interactions: metabolic, regulatory and signaling networks. Dynamics of metabolic networks; the stoichiometric matrix. Living systems as complex organizations; systems biology. Models of cellular dynamics. The implausibility of life based on a simplified probability estimate, and the origin of life problem.

At the level of a multicellular organism: Numbers and types of cells in multicellular organisms. Cell types as distinct attractors of a dynamical system. Stem cells and cellular differentiation. Pattern formation and development.

Brain structure: neurons and neural networks. Brain as an information processing system. Associative memory models. Memories as attractors of the neural network dynamics.

At the level of an ecosystem and the biosphere: Foodwebs. Feedback cycles and self-sustaining ecosystems.

Evolution: **(14 lectures)**

The mechanism of evolution: variation at the molecular level, selection at the level of the organism. Models of evolution. The concept of genotype-phenotype map. Examples.

References:

- Physics in Molecular Biology; Kim Sneppen & Giovanni Zocchi (CUP 2005)
- Biological Physics: Energy, Information, Life; Philip Nelson (W H Freeman & Co, NY, 2004)
- Physical Biology of the Cell (2nd Edition), Rob Phillips et al (Garland Science, Taylor & Francis Group, London & NY, 2013)
- An Introduction to Systems Biology; Uri Alon (Chapman and Hall/CRC, Special Indian Edition, 2013)
- Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd edition)

6.5.2. Skill Enhancement Course (SEC) for B.Sc. (Hons.) Physics and B.Sc. (Physics) with PCM, PMC and PEM Combinations

SEC-I: PHYSICS WORKSHOP SKILL
(Credits: 02)
30 Lectures

The aim of this course is to enable the students to familiar and experience with various mechanical and electrical tools through hands-on mode

Introduction: Measuring units. conversion to SI and CGS. Familiarization with meterscale, Vernier calliper, Screw gauge and their utility. Measure the dimension of a solid block, volume of cylindrical beaker/glass, diameter of a thin wire, thickness of metal sheet, etc. Use of Sextant to measure height of buildings, mountains, etc. **(4 Lectures)**

Mechanical Skill: Concept of workshop practice. Overview of manufacturing methods:casting, foundry, machining, forming and welding. Types of welding joints and welding defects. Common materials used for manufacturing like steel, copper, iron, metal sheets, composites and alloy, wood. Concept of machine processing, introduction to common machine tools like lathe, shaper, drilling, milling and surface machines. Cutting tools, lubricating oils. Cutting of a metal sheet using blade. Smoothening of cutting edge of sheet using file. Drilling of holes of different diameter in metal sheet and wooden block. Use of bench vice and tools for fitting. Make funnel using metal sheet. **(10 Lectures)**

Electrical and Electronic Skill: Use of Multimeter. Soldering of electrical circuitshaving discrete components (R, L, C, diode) and ICs on PCB. Operation of oscilloscope. Making regulated power supply. Timer circuit, Electronic switch using transistor and relay.**(10 Lectures)**

Introduction to prime movers: Mechanism, gear system, wheel, Fixing of gears withmotor axel. Lever mechanism, Lifting of heavy weight using lever. braking systems, pulleys, working principle of power generation systems. Demonstration of pulley experiment. **(6 Lectures)**

Reference Books:

- A text book in Electrical Technology - B L Theraja – S. Chand and Company.
- Performance and design of AC machines – M.G. Say, ELBS Edn.
- Mechanical workshop practice, K.C. John, 2010, PHI Learning Pvt. Ltd.
- Workshop Processes, Practices and Materials, Bruce J Black 2005, 3rd Edn., Editor Newnes [ISBN: 0750660732]
- New Engineering Technology, Lawrence Smyth/Liam Hennessy, The Educational Company of Ireland [ISBN: 0861674480]

SEC-II : COMPUTATIONAL PHYSICS
(Credits: 02)
Theory: 30 Lectures

The aim of this course is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- *Highlights the use of computational methods to solve physical problems*
- *Use of computer language as a tool in solving physics problems (applications)*
- *Course will consist of hands on training on the Problem solving on Computers.*

Introduction: Importance of computers in Physics, paradigm for solving physicsproblems for solution**.** Usage of linux as an Editor. **Algorithms and Flowcharts:** Algorithm: Definition, properties and development. Flowchart: Concept of flowchart, symbols, guidelines, types. Examples: Cartesian to Spherical Polar Coordinates, Rootsof Quadratic Equation, Sum of two matrices, Sum and Product of a finite series, calculation of sin(x) as a series, algorithm for plotting (1) lissajous figures and (2)trajectory of a projectile thrown at an angle with the horizontal. **(4 Lectures)**

Scientific Programming: Some fundamental Linux Commands (Internal and External commands). Development of FORTRAN, Basic elements of FORTRAN: Character Set, Constants and their types, Variables and their types, Keywords, Variable Declaration and concept of instruction and program. Operators: Arithmetic, Relational, Logical and Assignment Operators. Expressions: Arithmetic, Relational, Logical, Character and Assignment Expressions.

Fortran Statements: I/O Statements (unformatted/formatted), Executable and Non-Executable Statements, Layout of Fortran Program, Format of writing Program and concept of coding, Initialization and Replacement Logic. Examples from physics problems. **(5 Lectures)**

Control Statements: Types of Logic (Sequential, Selection, Repetition), Branching Statements (Logical **IF**, Arithmetic IF, Block IF, Nested Block IF, SELECT CASE and ELSE IF Ladder statements), Looping Statements (DO-CONTINUE, DO-ENDDO, DO-WHILE, Implied and Nested DO Loops), Jumping Statements (Unconditional GOTO, Computed GOTO, Assigned GOTO) Subscripted Variables (Arrays: Types of Arrays, DIMENSION Statement, Reading and Writing Arrays), Functions and Subroutines (Arithmetic Statement Function, Function Subprogram and Subroutine), RETURN, CALL, COMMON and EQUIVALENCE Statements), Structure, Disk I/O Statements, open a file, writing in a file, reading from a file. Examples from physics problems.

Programming:

1. Exercises on syntax on usage of FORTRAN
2. Usage of GUI Windows, Linux Commands, familiarity with DOS commands and working in an editor to write sources codes in FORTRAN.
3. To print out all natural even/ odd numbers between given limits.
4. To find maximum, minimum and range of a given set of numbers.
5. Calculating Euler number using exp(x) series evaluated at x=1 ` **(6 Lectures)**

Scientific word processing: Introduction to LaTeX: TeX/LaTeX word processor,preparing a basic LaTeX file, Document classes, Preparing an input file for LaTeX, Compiling LaTeX File, LaTeX tags for creating different environments, Defining LaTeX commands and environments, Changing the type style, Symbols from other languages. **Equation representation:** Formulae and equations, Figures and other floating bodies, Lining in columns- Tabbing and tabular environment, Generating table of contents, bibliography and citation, Making an index and glossary, List making environments, Fonts, Picture environment and colors, errors. **(6 Lectures)**

Visualization: Introduction to graphical analysis and its limitations. Introduction toGnuplot. importance of visualization of computational and computational data, basic Gnuplot commands: simple plots, plotting data from a file, saving and exporting, multiple data sets per file, physics with Gnuplot (equations, building functions, user defined variables and functions), Understanding data with Gnuplot

Hands on exercises:

1. To compile a frequency distribution and evaluate mean, standard deviation etc.
2. To evaluate sum of finite series and the area under a curve.
3. To find the product of two matrices
4. To find a set of prime numbers and Fibonacci series.
5. To write program to open a file and generate data for plotting using Gnuplot. Plotting trajectory of a projectile projected horizontally.
6. Plotting trajectory of a projectile projected making an angle with the horizontally.
7. Creating an input Gnuplot file for plotting a data and saving the output for seeing on the screen.
8. Saving it as an eps file and as a pdf file.
9. To find the roots of a quadratic equation.
10. Motion of a projectile using simulation and plot the output for visualization.
11. Numerical solution of equation of motion of simple harmonic oscillator and plot the outputs for visualization.
12. Motion of particle in a central force field and plot the output for visualization. **(9 Lectures)**

Reference Books:

- Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
- Computer Programming in Fortran 77”. V. Rajaraman (Publisher: PHI).
- LaTeX–A Document Preparation System”, Leslie Lamport (Second Edition, Addison-Wesley, 1994).
- Gnuplot in action: understanding data with graphs, Philip K Janert, (Manning 2010)
- Schaum’s Outline of Theory and Problems of Programming with Fortran, S Lipsdutz and A Poe, 1986Mc-Graw Hill Book Co.
- Computational Physics: An Introduction, R. C. Verma, et al. New Age International Publishers, New Delhi(1999)
- A first course in Numerical Methods, U.M. Ascher and C. Greif, 2012, PHI Learning
- Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

SEC-III: ELECTRICAL CIRCUITS AND NETWORK SKILLS
(Credits: 02)
Theory: 30 Lectures

The aim of this course is to enable the students to design and trouble shoots the electrical circuits, networks and appliances through hands-on mode

Basic Electricity Principles: Voltage, Current, Resistance, and Power. Ohm's law. Series, parallel, and series-parallel combinations. AC Electricity and DC Electricity. Familiarization with multimeter, voltmeter and ammeter. **(3 Lectures)**

Understanding Electrical Circuits: Main electric circuit elements and their combination. Rules to analyze DC sourced electrical circuits. Current and voltage drop across the DC circuit elements. Single-phase and three-phase alternating current sources. Rules to analyze AC sourced electrical circuits. Real, imaginary and complex power components of AC source. Power factor. Saving energy and money. **(4 Lectures)**

Electrical Drawing and Symbols: Drawing symbols. Blueprints. Reading Schematics. Ladder diagrams. Electrical Schematics. Power circuits. Control circuits. Reading of circuit schematics. Tracking the connections of elements and identify current flow and voltage drop. **(4 Lectures)**

Generators and Transformers: DC Power sources. AC/DC generators. Inductance, capacitance, and impedance. Operation of transformers. **(3 Lectures)**

Electric Motors: Single-phase, three-phase & DC motors. Basic design. Interfacing DC or AC sources to control heaters & motors. Speed & power of ac motor. **(4 Lectures)**

Solid-State Devices: Resistors, inductors and capacitors. Diode and rectifiers. Components in Series or in shunt. Response of inductors and capacitors with DC or AC sources **(3 Lectures)**

Electrical Protection: Relays. Fuses and disconnect switches. Circuit breakers. Overload devices. Ground-fault protection. Grounding and isolating. Phase reversal. Surge protection. Interfacing DC or AC sources to control elements (relay protection device) **(4 Lectures)**

Electrical Wiring: Different types of conductors and cables. Basics of wiring-Star anddelta connection. Voltage drop and losses across cables and conductors. Instruments to measure current, voltage, power in DC and AC circuits. Insulation. Solid and stranded cable. Conduit. Cable trays. Splices: wirenuts, crimps, terminal blocks, split bolts, and solder. Preparation of extension board. **(5 Lectures)**

Reference Books:

- A text book in Electrical Technology - B L Theraja - S Chand & Co.
- A text book of Electrical Technology - A K Theraja
- Performance and design of AC machines - M G Say ELBS Edn.

SEC-IV: BASIC INSTRUMENTATION SKILLS
(Credits: 02)
Theory: 30 Lectures

This course is to get exposure with various aspects of instruments and their usage through hands-on mode. Experiments listed below are to be done in continuation of the topics.

Basic of Measurement: Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. **Multimeter:** Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance. **(4 Lectures)**

Electronic Voltmeter: Advantage over conventional multimeter for voltagemeasurement with respect to input impedance and sensitivity. Principles of voltage, measurement (block diagram only). Specifications of an electronic Voltmeter/ Multimeter and their significance. **AC millivoltmeter:** Type of AC millivoltmeters: Amplifier- rectifier, and rectifier- amplifier. Block diagram ac millivoltmeter**,** specifications and their significance. **(4 Lectures)**

Cathode Ray **Oscilloscope:** Block diagram of basic CRO. Construction of CRT, Electron gun, electrostatic focusing and acceleration (Explanation only– no mathematical treatment), brief discussion on screen phosphor, visual persistence &chemical composition. Time base operation, synchronization. Front panel controls. Specifications of a CRO and their significance. **(6 Lectures)**

Use of CRO for the measurement of voltage (dc and ac frequency, time period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: Block diagram and principle of working. **(3 Lectures)**

Signal Generators and Analysis Instruments: Block diagram, explanation and specifications of low frequency signal generators. pulse generator, and function generator. Brief idea for testing, specifications. Distortion factor meter, wave analysis. **(4 Lectures)**

Impedance Bridges & Q-Meters: Block diagram of bridge. working principles of basic(balancing type) RLC bridge. Specifications of RLC bridge. Block diagram & working principles of a Q- Meter. Digital LCR bridges. **(3 Lectures)**

Digital Instruments: Principle and working of digital meters. Comparison of analog &digital instruments. Characteristics of a digital meter. Working principles of digital voltmeter. **(3 Lectures)**

Digital Multimeter: Block diagram and working of a digital multimeter. Working principle of time interval, frequency and period measurement using universal counter/frequency counter, time- base stability, accuracy and resolution. **(3 Lectures)**

The test of lab skills will be of the following test items:

1. Use of an oscilloscope.
2. CRO as a versatile measuring device.
3. Circuit tracing of Laboratory electronic equipment,
4. Use of Digital multimeter/VTVM for measuring voltages
5. Circuit tracing of Laboratory electronic equipment,
6. Winding a coil / transformer.
7. Study the layout of receiver circuit.

8. Trouble shooting a circuit
9. Balancing of bridges

Laboratory Exercises:

1. To observe the loading effect of a multimeter while measuring voltage across a low resistance and high resistance.
2. To observe the limitations of a multimeter for measuring high frequency voltage and currents.
3. To measure Q of a coil and its dependence on frequency, using a Q- meter.
4. Measurement of voltage, frequency, time period and phase angle using CRO.
5. Measurement of time period, frequency, average period using universal counter/ frequency counter.
6. Measurement of rise, fall and delay times using a CRO.
7. Measurement of distortion of a RF signal generator using distortion factor meter.
8. Measurement of R, L and C using a LCR bridge/ universal bridge.

Open Ended Experiments:

1. Using a Dual Trace Oscilloscope
2. Converting the range of a given measuring instrument (voltmeter, ammeter)

Reference Books:

- Text book in Electrical Technology - B L Theraja - S Chand and Co.
- Performance and design of AC machines - M G Say ELBS Edn.
- Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
- Logic circuit design, Shimon P. Vingron, 2012, Springer.
- Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
- Electronic Devices and circuits, S. Salivahanan & N. S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
- Electronic circuits: Handbook of design and applications, U.Tietze, Ch.Schenk, 2008, Springer
- Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India

SEC-V: RENEWABLE ENERGY AND ENERGY HARVESTING
(Credits: 02)
Theory: 30 Lectures

The aim of this course is not just to impart theoretical knowledge to the students but to provide them with exposure and hands-on learning wherever possible

Fossil fuels and Alternate Sources of energy: Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity. **(3 Lectures)**

Solar energy: Solar energy, its importance, storage of solar energy, solar pond, nonconvective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems. **(6 Lectures)**

Wind Energy harvesting: Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies. **(3 Lectures)**

Ocean Energy: Ocean Energy Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices. **(3 Lectures)**

Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Bio-mass. **(2 Lectures)**

Geothermal Energy: Geothermal Resources, Geothermal Technologies. **(2 Lectures)**

Hydro Energy: Hydropower resources, hydropower technologies, environmental impact of hydro power sources. **(2 Lectures)**

Piezoelectric Energy harvesting: Introduction, Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modeling piezoelectric generators, Piezoelectric Energy harvesting applications, Human power.

(4 Lectures)

Electromagnetic Energy Harvesting: Linear generators, physics mathematical models, recent applications **(2 Lectures)**

Carbon captured technologies, cell, batteries, power consumption **(2 Lectures)**

Environmental issues and Renewable sources of energy, sustainability. **(1 Lecture)**

Demonstrations and Experiments

1. Demonstration of Training modules on Solar energy, wind energy, etc.
2. Conversion of vibration to voltage using piezoelectric materials
3. Conversion of thermal energy into voltage using thermoelectric modules.

Reference Books:

- Non-conventional energy sources - G.D Rai - Khanna Publishers, New Delhi
- Solar energy - M P Agarwal - S Chand and Co. Ltd.
- Solar energy - Suhas P Sukhative Tata McGraw - Hill Publishing Company Ltd.
- Godfrey Boyle, “Renewable Energy, Power for a sustainable future”, 2004, Oxford University Press, in association with The Open University.
- Dr. P Jayakumar, Solar Energy: Resource Assesment Handbook, 2009
- J.Balfour, M.Shaw and S. Jarosek, Photovoltaics, Lawrence J Goodrich (USA).
- http://en.wikipedia.org/wiki/Renewable_energy

SEC-VI : TECHNICAL DRAWING
(Credits: 02)
Theory: 30 Lectures

Introduction: Drafting Instruments and their uses. lettering: construction and uses of various scales: dimensioning as per I.S.I. 696-1972. Engineering Curves: Parabola: hyperbola: ellipse:

cycloids, involute: spiral: helix and loci of points of simple moving mechanism.2D geometrical construction. Representation of 3D objects. Principles of projections. **(4 Lectures)**

Projections: Straight lines, planes and solids. Development of surfaces of right and oblique solids. Section of solids. **(6 Lectures)**

Object Projections: Orthographic projection. Interpenetration and intersection of solids. Isometric and oblique parallel projection of solids. **(4 Lectures)**

CAD Drawing: Introduction to CAD and Auto CAD, precision drawing and drawing aids, Geometric shapes, Demonstrating CAD- specific skills (graphical user interface. Create, retrieve, edit, and use symbol libraries. Use inquiry commands to extract drawing data). Control entity properties. Demonstrating basic skills to produce 2-D and 3-Ddrawings. 3D modeling with Auto CAD (surfaces and solids), 3D modeling with sketch up, annotating in Auto CAD with text and hatching, layers, templates & design center, advanced plotting (layouts, viewports), office standards, dimensioning, internet and collaboration, Blocks, Drafting symbols, attributes, extracting data. basic printing, editing tools, Plot/Print drawing to appropriate scale.

(16 Lectures)

Reference Books:

- K. Venugopal, and V. Raja Prabhu. Engineering Graphic, New Age International
- AutoCAD 2014 & AutoCAD 2014/Donnie Gladfelter/Sybex/ISBN:978-1-118-57510-9
- Architectural Design with Sketchup/Alexander Schreyer/John Wiley & Sons/ISBN: 978-1-118-12309-6

SEC-VII : RADIATION SAFETY
(Credits: 02)
Theory: 30 Lectures

The aim of this course is for awareness and understanding regarding radiation hazards and safety. The list of laboratory skills and experiments listed below the course are to be done in continuation of the topics

Basics of Atomic and Nuclear Physics: Basic concept of atomic structure; X rays characteristic and production; concept of bremsstrahlung and auger electron, The composition of nucleus and its properties, mass number, isotopes of element, spin, binding energy, stable and unstable isotopes, law of radioactive decay, Mean life and half life, basic concept of alpha, beta and gamma decay, concept of cross section and kinematics of nuclear reactions, types of nuclear reaction, Fusion, fission. **(6 Lectures)**

Interaction of Radiation with matter: Types of Radiation: Alpha, Beta, Gamma andNeutron and their sources, sealed and unsealed sources, **Interaction of Photons** - Photo-electric effect, Compton Scattering, Pair Production, Linear and Mass Attenuation Coefficients, **Interaction of Charged Particles:** Heavy charged particles - Beth-Bloch Formula, Scaling laws, Mass Stopping Power, Range, Straggling, Channeling and Cherenkov radiation. Beta Particles- Collision and Radiation loss (Bremsstrahlung),

Interaction of Neutrons- Collision, slowing down and Moderation. **(7 Lectures)**

Radiation detection and monitoring devices: Radiation Quantities and Units: Basicidea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, Annual Limit of Intake (ALI) and derived Air Concentration (DAC). **Radiation detection:** Basic concept and working principle of *gas detectors* (Ionization Chambers, Proportional Counter, Multi-Wire ProportionalCounters (MWPC) and Gieger Muller Counter), *Scintillation Detectors*(Inorganic and Organic Scintillators), *Solid States Detectors* and *Neutron Detectors, Thermo luminescent Dosimetry.* **(7 Lectures)**

Radiation safety management: Biological effects of ionizing radiation, Operational limits and basics of radiation hazards evaluation and control: radiation protection standards, International Commission on Radiological Protection (ICRP) principles, justification, optimization, limitation, introduction of safety and risk management of radiation. Nuclear waste and disposal management. Brief idea about Accelerator driven Sub-critical system (ADS) for waste management. **(5 Lectures)**

Application of nuclear techniques: Application in medical science (e.g., MRI, PET, Projection Imaging Gamma Camera, radiation therapy), Archaeology, Art, Crime detection, Mining and oil. *Industrial Uses:* Tracing, Gauging, Material Modification, Sterization, Food preservation.

(5 Lectures)

Experiments:

1. Study the background radiation levels using Radiation meter

Characteristics of Geiger Muller (GM) Counter:

2) Study of characteristics of GM tube and determination of operating voltage and plateau length using background radiation as source (without commercial source).
3) Study of counting statistics using background radiation using GM counter.
4) Study of radiation in various materials (e.g. KSO4 etc.). Investigation of possible radiation in different routine materials by operating GM at operating voltage.
5) Study of absorption of beta particles in Aluminum using GM counter.
6) Detection of α particles using reference source & determining its half life using spark counter
7) Gamma spectrum of Gas Light mantle (Source of Thorium)

Reference Books

1. W.E. Burcham and M. Jobes – Nuclear and Particle Physics – Longman (1995)
2. G.F.Knoll, Radiation detection and measurements
3. Thermoluninescense Dosimetry, Mcknlay, A.F., Bristol, Adam Hilger (Medical Physics Handbook 5)
4. W.J. Meredith and J.B. Massey, "Fundamental Physics of Radiology". John Wright and Sons, UK, 1989.
5. J.R. Greening, "Fundamentals of Radiation Dosimetry", Medical Physics Hand Book Series, No.6, Adam Hilger Ltd., Bristol 1981.
6. Practical Applications of Radioactivity and Nuclear Radiations, G.C. Lowental and P.L. Airey, Cambridge University Press, U.K., 2001
7. A. Martin and S.A. Harbisor, An Introduction to Radiation Protection, John Willey & Sons, Inc. New York, 1981.

8. NCRP, ICRP, ICRU, IAEA, AERB Publications.
9. W.R. Hendee, "Medical Radiation Physics", Year Book – Medical Publishers Inc. London, 1981

SEC-VIII: APPLIED OPTICS
(Credits: 02)
THEORY: 30 Lectures

Theory includes only qualitative explanation. Minimum five experiments should be performed covering minimum three sections.

(i) Sources and Detectors **(9 Lectures)**

Lasers, Spontaneous and stimulated emissions, Theory of laser action, Einstein's coefficients, Light amplification, Characterization of laser beam, He-Ne laser, Semiconductor lasers.

Experiments on Lasers:

a. Determination of the grating radial spacing of the Compact Disc (CD) by reflection using He-Ne or solid state laser.
b. To find the width of the wire or width of the slit using diffraction pattern obtained by a He-Ne or solid state laser.
c. To find the polarization angle of laser light using polarizer and analyzer
d. Thermal expansion of quartz using laser

Experiments on Semiconductor Sources and Detectors:

a. V-I characteristics of LED
b. Study the characteristics of solid state laser
c. Study the characteristics of LDR
d. Photovoltaic Cell
e. Characteristics of IR sensor

(ii) Fourier Optics **(6 Lectures)**

Concept of Spatial frequency filtering, Fourier transforming property of a thin lens

Experiments on Fourier Optics:

a. Fourier optic and image processing

1. Optical image addition/subtraction
2. Optical image differentiation
3. Fourier optical filtering
4. Construction of an optical 4f system

b. Fourier Transform Spectroscopy

Fourier Transform Spectroscopy (FTS) is a powerful method for measuring emission and absorption spectra, with wide application in atmospheric remote sensing, NMR spectrometry and forensic science.

Experiment:

To study the interference pattern from a Michelson interferometer as a function of mirror separation in the interferometer. The resulting interferogram is the Fourier transform of the power spectrum of the source. Analysis of experimental interferograms allows one to determine the transmission characteristics of several interference filters. Computer simulation can also be done.

(iii) Holography **(6 Lectures)**

Basic principle and theory: coherence, resolution, Types of holograms, white light reflection hologram, application of holography in microscopy, interferometry, and character recognition

Experiments on Holography and interferometry:

1. Recording and reconstructing holograms
2. Constructing a Michelson interferometer or a Fabry Perot interferometer
3. Measuring the refractive index of air
4. Constructing a Sagnac interferometer
5. Constructing a Mach-Zehnder interferometer
6. White light Hologram

(iv) Photonics: Fibre Optics **(9 Lectures)**

Optical fibres and their properties, Principal of light propagation through a fibre, The numerical aperture, Attenuation in optical fibre and attenuation limit, Single mode and multimode fibres, Fibre optic sensors: Fibre Bragg Grating

Experiments on Photonics: Fibre Optics

a. To measure the numerical aperture of an optical fibre
b. To study the variation of the bending loss in a multimode fibre
c. To determine the mode field diameter (MFD) of fundamental mode in a single-mode fibre by measurements of its far field Gaussian pattern
d. To measure the near field intensity profile of a fibre and study its refractive index profile
e. To determine the power loss at a splice between two multimode fibre

Reference Books:

- Fundamental of optics, F. A. Jenkins & H. E. White, 1981, Tata McGraw hill.
- ASERS: Fundamentals & applications, K.Thyagrajan & A.K.Ghatak, 2010, Tata McGraw Hill
- Fibre optics through experiments, M.R.Shenoy, S.K.Khijwania, et.al. 2009, Viva Books
- Nonlinear Optics, Robert W. Boyd, (Chapter-I), 2008, Elsevier.
- Optics, Karl Dieter Moller, Learning by computing with model examples, 2007, Springer.
- Optical Systems and Processes, Joseph Shamir, 2009, PHI Learning Pvt. Ltd.
- Optoelectronic Devices and Systems, S.C. Gupta, 2005, PHI Learning Pvt. Ltd.
- Optical Physics, A.Lipson, S.G.Lipson, H.Lipson, 4th Edn., 1996, Cambridge Univ. Press

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SEC-IX: WEATHER FORECASTING
(Credits: 02)
Theory: 30 Lectures

The aim of this course is not just to impart theoretical knowledge to the students but to enable them to develop an awareness and understanding regarding the causes and effects of different weather phenomenon and basic forecasting techniques

Introduction to atmosphere: Elementary idea of atmosphere: physical structure and composition; compositional layering of the atmosphere; variation of pressure and temperature with height; air temperature; requirements to measure air temperature; temperature sensors: types; atmospheric pressure: its measurement; cyclones and anticyclones: its characteristics.

(9 Lectures)

Measuring the weather: Wind; forces acting to produce wind; wind speed direction: units, its direction; measuring wind speed and direction; humidity, clouds and rainfall, radiation: absorption, emission and scattering in atmosphere; radiation laws. **(4 Lectures)**

Weather systems: Global wind systems; air masses and fronts: classifications; jet streams; local thunderstorms; tropical cyclones: classification; tornadoes; hurricanes. **(3 Lectures)**

Climate and Climate Change: Climate: its classification; causes of climate change; global warming and its outcomes; air pollution; aerosols, ozone depletion, acid rain, environmental issues related to climate. **(6 Lectures)**

Basics of weather forecasting: Weather forecasting: analysis and its historical background; need of measuring weather; types of weather forecasting; weather forecasting methods; criteria of choosing weather station; basics of choosing site and exposure; satellites observations in weather forecasting; weather maps; uncertainty and predictability; probability forecasts.

(8 Lectures)

Demonstrations and Experiments:

1. Study of synoptic charts & weather reports, working principle of weather station.
2. Processing and analysis of weather data:

(a) To calculate the sunniest time of the year.

(b) To study the variation of rainfall amount and intensity by wind direction.

(c) To observe the sunniest/driest day of the week.

(d) To examine the maximum and minimum temperature throughout the year.

(e) To evaluate the relative humidity of the day.

(f) To examine the rainfall amount month wise.

3. Exercises in chart reading: Plotting of constant pressure charts, surfaces charts, upper wind charts and its analysis.
4. Formats and elements in different types of weather forecasts/ warning (both aviation and non aviation)

Reference books:

1. Aviation Meteorology, I.C. Joshi, 3rd edition 2014, Himalayan Books
2. The weather Observers Hand book, Stephen Burt, 2012, Cambridge University Press.
3. Meteorology, S.R. Ghadekar, 2001, Agromet Publishers, Nagpur.
4. Text Book of Agrometeorology, S.R. Ghadekar, 2005, Agromet Publishers, Nagpur.
5. Why the weather, Charls Franklin Brooks, 1924, Chpraman & Hall, London.
6. Atmosphere and Ocean, John G. Harvey, 1995, The Artemis Press.

6.5.3. Generic Elective Courses (GEC) for Minor Physics Course in the B.Sc.(Hons.) for other mains.

and

Core Courses (CC) and Discipline Specific Elective Courses (DSEC) for B.Sc. (General) Courses with PCM, PMC and PEM combinations

CC-I & GEC-I : MECHANICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Vectors: Vector algebra. Scalar and vector products. Derivatives of a vector with respect to a parameter. **(4 Lectures)**

Ordinary Differential Equations: 1storder homogeneous differential equations. 2ndorder homogeneous differential equations with constant coefficients. **(6 Lectures)**

Laws of Motion: Frames of reference. Newton's Laws of motion. Dynamics of a system of particles. Centre of Mass. **(10 Lectures)**

Momentum and Energy: Conservation of momentum. Work and energy. Conservation of energy. Motion of rockets. **(6 Lectures)**

Rotational Motion: Angular velocity and angular momentum. Torque. Conservation of angular momentum. **(5 Lectures)**

Gravitation: Newton's Law of Gravitation. Motion of a particle in a central force field (motion is in a plane, angular momentum is conserved, areal velocity is constant). Kepler's Laws (statement only). Satellite in circular orbit and applications. Geosynchronous orbits. Basic idea of global positioning system (GPS). Weightlessness. Physiological effects on astronauts.

(8 Lectures)

Oscillations: Simple harmonic motion. Differential equation of SHM and its solutions. Kinetic and Potential Energy, Total Energy and their time averages. Damped oscillations. **(6 Lectures)**

Elasticity: Hooke's law - Stress-strain diagram - Elastic moduli-Relation between elastic constants - Poisson's Ratio-Expression for Poisson's ratio in terms of elastic constants - Work done in stretching and work done in twisting a wire - Twisting couple on a cylinder - Determination of Rigidity modulus by static torsion – Torsional pendulum-Determination of Rigidity modulus and moment of inertia - q, η and □ by Searles method. **(8 Lectures)**

Special Theory of Relativity: Constancy of speed of light. Postulates of Special Theory of Relativity. Length contraction. Time dilation. Relativistic addition of velocities. **(7 Lectures)**

Note: *Students are not familiar with vector calculus. Hence all examples involve differentiation either in one dimension or with respect to the radial coordinate*

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Reference Books:

- University Physics. F.W. Sears, M.W. Zemansky and H.D. Young, 13/e, 1986. Addison-Wesley
- Mechanics Berkeley Physics, v.1: Charles Kittel, et. al. 2007, Tata McGraw-Hill.
- Physics – Resnick, Halliday & Walker 9/e, 2010, Wiley
- Engineering Mechanics, Basudeb Bhattacharya, 2nd edn., 2015, Oxford University Press
- University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

PHYSICS LAB: CC-I & GEC-I LAB: MECHANICS
60 Lectures

1. Measurements of length (or diameter) using vernier caliper, screw gauge and travelling microscope.
2. To determine the Height of a Building using a Sextant.
3. To determine the Moment of Inertia of a Flywheel.
4. To determine the Young's Modulus of a Wire by Optical Lever Method.
5. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.
6. To determine the Elastic Constants of a Wire by Searle's method.
7. To determine g by Bar Pendulum.
8. To determine g by Kater's Pendulum.
9. To study the Motion of a Spring and calculate (a) Spring Constant, (b) g.

Reference Books:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
- Engineering Practical Physics, S.Panigrahi & B.Mallick,2015, Cengage Learning India Pvt. Ltd.
- A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.

CC-II & GEC-II : ELECTRICITY AND MAGNETISM
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Vector Analysis: Review of vector algebra (Scalar and Vector product), gradient, divergence, Curl and their significance, Vector Integration, Line, surface and volume integrals of Vector fields, Gauss-divergence theorem and Stoke's theorem of vectors (statement only). **(12 Lectures)**

Electrostatics: Electrostatic Field, electric flux, Gauss's theorem of electrostatics. Applications of Gauss theorem- Electric field due to point charge, infinite line of charge, uniformly charged spherical shell and solid sphere, plane charged sheet, charged conductor. Electric potential as line integral of electric field, potential due to a point charge, electric dipole, uniformly charged spherical shell and solid sphere. Calculation of electric field from potential. Capacitance of an isolated spherical conductor. Parallel plate, spherical and cylindrical condenser. Energy per unit volume in electrostatic field. Dielectric medium, Polarisation, Displacement vector. Gauss's theorem in dielectrics. Parallel plate capacitor completely filled with dielectric. **(22 Lectures)**

Magnetism: Magnetostatics: Biot-Savart's law and its applications- straight conductor, circular coil, solenoid carrying current. Divergence and curl of magnetic field. Magnetic vector potential. Ampere's circuital law. Magnetic properties of materials: Magnetic intensity, magnetic induction, permeability, magnetic susceptibility. Brief introduction of dia-, para-and ferro- magnetic materials. **(10 Lectures)**

Electromagnetic Induction: Faraday's laws of electromagnetic induction, Lenz'slaw, self and mutual inductance, L of single coil, M of two coils. Energy stored in magnetic field.**(6 Lectures)**

Maxwell`s equations and Electromagnetic wave propagation: Equation of continuity of current, Displacement current, Maxwell's equations, Poynting vector, energy density in electromagnetic field, electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, polarization. **(10 Lectures)**

Reference Books:

- Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
- Electricity & Magnetism, J.H. Fewkes & J.Yarwood. Vol. I, 1991, Oxford Univ. Press
- Electricity and Magnetism, D C Tayal, 1988, Himalaya Publishing House.
- University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
- D.J.Griffiths, Introduction to Electrodynamics, 3rd Edn, 1998, Benjamin Cummings.

CC-II & GEC-II LAB: ELECTRICITY AND MAGNETISM
60 Lectures

(a) To use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, and (d) checking electrical fuses.

1. Ballistic Galvanometer:
   (i) Measurement of charge and current sensitivity
   (ii) Measurement of CDR
   (iii)Determine a high resistance by Leakage Method
   (iv)To determine Self Inductance of a Coil by Rayleigh's Method.
2. To compare capacitances using De'Sauty's bridge.
3. Measurement of field strength B and its variation in a Solenoid (Determine dB/dx)
4. To study the Characteristics of a Series RC Circuit.
5. To study a series LCR circuit LCR circuit and determine its (a) Resonant frequency, (b) Quality factor

(b) To study a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q

6. To determine a Low Resistance by Carey Foster's Bridge.
7. To verify the Thevenin and Norton theorems
8. To verify the Superposition, and Maximum Power Transfer Theorems

Reference Books:

- Advanced Practical Physics for students, B.L.Flint & H.T.Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Ed.2011, Kitab Mahal
- Engineering Practical Physics, S.Panigrahi & B.Mallick,2015, Cengage Learning India Pvt. Ltd.

CC-III & GEC-III: THERMAL PHYSICS AND STATISTICAL MECHANICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Laws of Thermodynamics: Thermodynamic Description of system: Zeroth Law of thermodynamics and temperature. First law and internal energy, conversion of heat into work, Various Thermodynamical Processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Coefficient, Reversible and irreversible processes, Second law and Entropy, Carnot's cycle & theorem, Entropy changes in reversible & irreversible processes, Entropy-temperature diagrams, Third law of thermodynamics, Unattainability of absolute zero. **(22 Lectures)**

Thermodynamical Potentials: Enthalpy, Gibbs, Helmholtz and Internal Energy functions, Maxwell's relations and applications - Joule-Thompson Effect, Clausius-Clapeyron Equation, Expression for (CP – CV), CP/CV, TdS equations. **(10 Lectures)**

Kinetic Theory of Gases: Derivation of Maxwell's law of distribution of velocitiesand its experimental verification, Mean free path (Zeroth Order), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case), Law of equipartition of energy (no derivation) and its applications to specific heat of gases; mono-atomic and diatomic gases. **(10 Lectures)**

Theory of Radiation: Blackbody radiation, Spectral distribution, Concept of Energy Density, Derivation of Planck's law, Deduction of Wien's distribution law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law. **(6 Lectures)**

Statistical Mechanics: Phase space, Macrostate and Microstate, Entropy and Thermodynamic probability, Maxwell-Boltzmann law - distribution of velocity - Quantum statistics - Fermi-Dirac distribution law - electron gas - Bose-Einstein distribution law - photon gas - comparison of three statistics. **(12 Lectures)**

Reference Books:

- Thermal Physics, S. Garg, R. Bansal and C. Ghosh, 1993, Tata McGraw-Hill.
- A Treatise on Heat, Meghnad Saha, and B.N. Srivastava, 1969, Indian Press.
- Thermodynamics, Enrico Fermi, 1956, Courier Dover Publications.
- Heat and Thermodynamics, M.W.Zemasky and R. Dittman, 1981, McGraw Hill
- Thermodynamics, Kinetic theory & Statistical thermodynamics, F.W.Sears and G.L. Salinger. 1988, Narosa
- University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
- Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. chand Publications.

CC-III & GECIII LAB: THERMAL PHYSICS AND STATISTICAL MECHANICS

60 Lectures

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. Measurement of Planck's constant using black body radiation.
3. To determine Stefan's Constant.
4. To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
5. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
6. To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method.
7. To determine the temperature co-efficient of resistance by Platinum resistance thermometer.

8. To study the variation of thermo emf across two junctions of a thermocouple with temperature.
9. To record and analyze the cooling temperature of an hot object as a function of time using a thermocouple and suitable data acquisition system
10. To calibrate Resistance Temperature Device (RTD) using Null Method/Off-Balance Bridge

Reference Books:

- Advanced Practical Physics for students, B.L.Flint & H.T.Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
- A Laboratory Manual of Physics for Undergraduate Classes, D.P. Khandelwal, 1985, Vani Publication.

CC-IV & GEC-IV: WAVES AND OPTICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Superposition of Two Collinear Harmonic oscillations: Linearity & Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats). **(4 Lectures)**

Superposition of Two Perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses. **(2 Lectures)**

Waves Motion- General: Transverse waves on a string. Travelling and standing waves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity. **(7 Lectures)**

Fluids: Surface Tension: Synclastic and anticlastic surface - Excess of pressure -Application to spherical and cylindrical drops and bubbles - variation of surface tension with temperature - Jaegar's method. Viscosity - Rate flow of liquid in a capillary tube - Poiseuille's formula - Determination of coefficient of viscosity of a liquid - Variations of viscosity of liquid with temperature- lubrication. **(6 Lectures)**

Sound: Simple harmonic motion - forced vibrations and resonance - Fourier's Theorem - Application to saw tooth wave and square wave - Intensity and loudness of sound - Decibels - Intensity levels - musical notes - musical scale. Acoustics of buildings: Reverberation and time of reverberation - Absorption coefficient - Sabine's formula - measurement of reverberation time - Acoustic aspects of halls and auditoria. **(6 Lectures)**

Wave Optics: Electromagnetic nature of light. Definition and Properties of wave front. Huygens Principle. **(3 Lectures)**

Interference: Interference: Division of amplitude and division of wavefront. Young'sDouble Slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: measurement of wavelength and refractive index. **(10 Lectures)**

Michelson's Interferometer: Idea of form of fringes (no theory needed), Determination of wavelength, Wavelength difference, Refractive index, and Visibility of fringes. **(3 Lectures)**

Diffraction: Fraunhofer diffraction- Single slit; Double Slit. Multiple slits and Diffraction grating. Fresnel Diffraction: Half-period zones. Zone plate. Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis. **(14 Lectures)**

Polarization: Transverse nature of light waves. Plane polarized light – production and analysis. Circular and elliptical polarization. **(5 Lectures)**

Reference Books:

- Fundamentals of Optics, F.A Jenkins and H.E White, 1976, McGraw-Hill
- Principles of Optics, B.K. Mathur, 1995, Gopal Printing
- Fundamentals of Optics, H.R. Gulati and D.R. Khanna, 1991, R. Chand Publications
- University Physics. F.W. Sears, M.W. Zemansky and H.D. Young. 13/e, 1986. Addison-Wesley

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CC-IV & GEC-IV LAB: WAVES AND OPTICS

60 Lectures

1. To investigate the motion of coupled oscillators
2. To determine the Frequency of an Electrically Maintained Tuning Fork by Melde's Experiment and to verify λ^2 – T Law.
3. To study Lissajous Figures
4. Familiarization with Schuster`s focussing; determination of angle of prism.
5. To determine the Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
6. To determine the Refractive Index of the Material of a Prism using Sodium Light.
7. To determine Dispersive Power of the Material of a Prism using Mercury Light
8. To determine the value of Cauchy Constants.
9. To determine the Resolving Power of a Prism.
10. To determine wavelength of sodium light using Fresnel Biprism.
11. To determine wavelength of sodium light using Newton's Rings.
12. To determine the wavelength of Laser light using Diffraction of Single Slit.
13. To determine wavelength of (1) Sodium and (2) Spectral lines of the Mercury light using plane diffraction Gratin
14. To determine the Resolving Power of a Plane Diffraction Grating.
15. To measure the intensity using photosensor and laser in diffraction patterns of single and double slits.

Reference Books:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4^{th} Edition, reprinted 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11^{th} Edition, 2011, Kitab Mahal, New Delhi.

GEC-V & DSEC-I: DIGITAL, ANALOG CIRCUITS AND INSTRUMENTATION

(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

UNIT-1: Digital Circuits:

Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion, AND, OR and NOT Gates (Realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates. **(4 Lectures)**

De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Minterms and Maxterms. Conversion of a Truth Table into an Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map. **(5 Lectures)**

Binary Addition. Binary Subtraction using 2's Complement Method). Half Adders and Full Adders and Subtractors, 4-bit binary Adder-Subtractor. **(4 Lectures)**

UNIT-2: Semiconductor Devices and Amplifiers:

Semiconductor Diodes: P and N type semiconductors. Barrier Formation in PN Junction Diode. Qualitative Idea of Current Flow Mechanism in Forward and Reverse Biased Diode. PN junction and its characteristics. Static and Dynamic Resistance. Principle and structure of (1) LEDs, (2) Photodiode, (3) Solar Cell. **(5 Lectures)**

Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Active, Cutoff & Saturation regions Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line & Q-point. Voltage Divider Bias Circuit for CE Amplifier. h-parameter Equivalent Circuit. Analysis of single-stage CE amplifier using hybrid Model. Input & output Impedance. Current, Voltage and Power gains. Class A, B & C Amplifiers. **(12 Lectures)**

UNIT-3: Operational Amplifiers (Black Box approach):

Characteristics of an Ideal and Practical Op-Amp (IC 741), Open-loop and closed-loop Gain. CMRR, concept of Virtual ground. Applications of Op-Amps: (1) Inverting and non-inverting Amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Zero crossing detector. **(13 Lectures)**

Sinusoidal Oscillators: Barkhausen's Criterion for Self-sustained Oscillations. Determination of Frequency of RC Oscillator **(5 Lectures)**

UNIT-4: Instrumentations:

Introduction to CRO: Block Diagram of CRO. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference. **(3 Lectures)**

Power Supply: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers Calculation of Ripple Factor and Rectification Efficiency, Basic idea about capacitor filter, Zener Diode and Voltage Regulation. **(6 Lectures)**

Timer IC: IC 555 Pin diagram and its application as Astable and Monostable Multivibrator. **(3 Lectures)**

Reference Books:

- Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
- Electronic devices & circuits, S. Salivahanan & N.S. Kumar, 2012, Tata Mc-Graw Hill
- Microelectronic Circuits, M.H. Rashid, 2nd Edn., 2011, Cengage Learning.
- Modern Electronic Instrumentation and Measurement Tech., Helfrick and Cooper, 1990, PHI Learning
- Digital Principles and Applications, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw Hill
- Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6th Edn., Oxford University Press.

- Fundamentals of Digital Circuits, A. Anand Kumar, 2nd Edition, 2009, PHI Learning Pvt. Ltd.
- OP-AMP & Linear Digital Circuits, R.A. Gayakwad, 2000, PHI Learning Pvt. Ltd.

GEC-V & DSEC-I LAB: DIGITAL, ANALOG CIRCUITS AND INSTRUMENTS

60 Lectures

1. To measure (a) Voltage, and (b) Frequency of a periodic waveform using CRO
2. To verify and design AND, OR, NOT and XOR gates using NAND gates.
3. To minimize a given logic circuit.
4. Half adder, Full adder and 4-bit Binary Adder.
5. Adder-Subtractor using Full Adder I.C.
6. To design an astable multivibrator of given specifications using 555 Timer.
7. To design a monostable multivibrator of given specifications using 555 Timer.
8. To study IV characteristics of PN diode, Zener and Light emitting diode
9. To study the characteristics of a Transistor in CE configuration.
10. To design a CE amplifier of given gain (mid-gain) using voltage divider bias.
11. To design an inverting amplifier of given gain using Op-amp 741 and study its frequency response.
12. To design a non-inverting amplifier of given gain using Op-amp 741 and study its Frequency Response.
13. To study Differential Amplifier of given I/O specification using Op-amp.
14. To investigate a differentiator made using op-amp.
15. To design a Wien Bridge Oscillator using an op-amp.

Reference Books:

- Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-Graw Hill.
- Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
- OP-Amps & Linear Integrated Circuit, R.A. Gayakwad, 4th Edn, 2000, Prentice Hall.
- Electronic Principle, Albert Malvino, 2008, Tata Mc-Graw Hill.

GEC-VI & DSEC-II: ELEMENTS OF MODERN PHYSICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Planck's quantum, Planck's constant and light as a collection of photons; Photo-electric effect and Compton scattering. De Broglie wavelength and matter waves; Davisson-Germer experiment. **(8 Lectures)**

Problems with Rutherford model- instability of atoms and observation of discrete atomic spectra; Bohr's quantization rule and atomic stability; calculation of energy levels for hydrogen like atoms and their spectra. **(4 Lectures)**

Position measurement- gamma ray microscope thought experiment; Wave-particle duality, Heisenberg uncertainty principle- impossibility of a particle following a trajectory; Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle. **(4 Lectures)**

Two slit interference experiment with photons, atoms & particles; linear superposition principle as a consequence; Matter waves and wave amplitude; Schrodinger equation for non-relativistic particles; Momentum and Energy operators; stationary states; physical interpretation of wavefunction, probabilities and normalization; Probability and probability current densities in one dimension. **(11 Lectures)**

One dimensional infinitely rigid box- energy eigenvalues and eigenfunctions, normalization; Quantum dot as an example; Quantum mechanical scattering and tunnelling in one dimension - across a step potential and across a rectangular potentialbarrier. **(12 Lectures)**

Size and structure of atomic nucleus and its relation with atomic weight; Impossibility of an electron being in nucleus as a consequence of the uncertainty principle. Nature of nuclear force, NZ graph, semi-empirical mass formula and binding energy. **(6 Lectures)**

Radioactivity: stability of nucleus; Law of radioactive decay; Mean life and half life α decay; β decay - energy released, spectrum and Pauli's prediction of neutrino; γ-ray emission.

(11 Lectures)

Fission and fusion - mass deficit, relativity and generation of energy; Fission - nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium 235; Fusion and thermonuclear reactions. **(4 Lectures)**

Reference Books:

- Concepts of Modern Physics, Arthur Beiser, 2009, McGraw-Hill
- Modern Physics, J.R. Taylor, C.D. Zafiratos, M.A. Dubson,2009, PHI Learning
- Six Ideas that Shaped Physics:Particle Behave like Waves, Thomas A. Moore, 2003, McGraw Hill
- Quantum Physics, Berkeley Physics,Vol.4. E.H. Wichman, 2008, Tata McGraw-Hill Co.
- Modern Physics, R.A. Serway, C.J. Moses, and C.A.Moyer, 2005, Cengage Learning
- Modern Physics, G. Kaur and G.R. Pickrell, 2014, McGraw Hill

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GEC-VI & DSEC-II LAB: ELEMENTS OF MODERN PHYSICS

60 Lectures

1. To determine value of Boltzmann constant using V-I characteristic of PN diode.
2. To determine work function of material of filament of directly heated vacuum diode.
3. To determine the ionization potential of mercury.
4. To determine value of Planck's constant using LEDs of at least 4 different colours.
5. To determine the wavelength of H-alpha emission line of Hydrogen atom.
6. To determine the absorption lines in the rotational spectrum of Iodine vapour.
7. To study the diffraction patterns of single and double slits using laser and measure its intensity variation using Photosensor & compare with incoherent source – Na.
8. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
9. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
10. To setup the Millikan oil drop apparatus and determine the charge of an electron.

Reference Books:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.

GEC-VII & DSEC-III: MATHEMATICAL PHYSICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

The emphasis of the course is on applications in solving problems of interest to physicists. Students to be examined on the basis of problems, seen and unseen.

Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers. **(6 Lectures)**

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. **(10 Lectures)**

Frobenius Method and Special Functions: Singular Points of Second Order LinearDifferential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite & Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Orthogonality. Simple recurrence relations. **(16 Lectures)**

Some Special Integrals: Beta and Gamma Functions and Relation between them.Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral). **(4 Lectures)**

Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry.

(10 Lectures)

Complex Analysis: Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy’s Integral formula. **(14 Lectures)**

Reference Books:

- Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.
- Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.
- Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole.
- An Introduction to Ordinary Differential Equations, E.A Coddington, 1961, PHI Learning
- Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
- Partial Differential Equations for Scientists and Engineers, S.J. Farlow, 1993, Dover Publications.
- Mathematical methods for Scientists & Engineers, D.A. McQuarrie, 2003, Viva Books.

GEC-VII & DSEC-III LAB: MATHEMATICAL PHYSICS
60 Lectures

The aim of this Lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- *The course will consist of lectures (both theory and practical) in the Lab*
- *Evaluation done on the basis of formulating the problem*

- *Aim at teaching students to construct the computational problem to be solved*

Topics	Description with Applications
Introduction and Overview	Computer architecture and organization, memory and Input/output devices
Basics of scientific computing	Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow &overflow-emphasize the importance of making equations in terms of dimensionless variables, Iterative methods
Errors and error Analysis	Truncation and round off errors, Absolute and relative errors, Floating point computations.
Review of C & C++ Programming fundamentals	Introduction to Programming, constants, variables and data types, operators and Expressions, I/O statements, scanf and printf, c in and c out, Manipulators for data formatting, Control statements (decision making and looping statements) (If-statement. If-else Statement. Nested if Structure. Else-if Statement. Ternary Operator. Goto Statement. Switch Statement. Unconditional and Conditional Looping. While Loop. Do-While Loop. FOR Loop. Break and Continue Statements. Nested Loops), Arrays (*1D & 2D*) and strings, user defined functions, Structures and Unions, Idea of classes and objects
Programs: using C/C++ language	Sum & average of a list of numbers, largest of a given list of numbers and its location in the list, sorting of numbers in ascending descending order, Binary search
Random number generation	Area of circle, area of square, volume of sphere, value of $\boldsymbol{\pi}$
Solution of Algebraic and Transcendental equations by Bisection, Newton Raphson and Secant methods	Solution of linear and quadratic equation, solving $\alpha = \tan\alpha\,; I = I_0\left(\frac{\sin\alpha}{\alpha}\right)^2$ in optics
Interpolation by Newton Gregory Forward and Backward difference formula, Error estimation of linear interpolation	Evaluation of trigonometric functions e.g. *sinθ, cosθ, tan θ, etc.*
Numerical differentiation (Forward and Backward difference formula) and Integration (Trapezoidal and Simpson rules), Monte Carlo method	Given Position with equidistant time data to calculate velocity and acceleration and vice versa. Find the area of B-H Hysteresis loop
Solution of Ordinary	First order differential equation

Differential Equations (ODE) First order Differential equation Euler, modified Euler and Runge-Kutta (RK) second and fourth order methods	• Radioactive decay • Current in RC, LC circuits with DC source • Newton's law of cooling • Classical equations of motion Attempt following problems using RK 4 order method: • Solve the coupled differential equations $\frac{dx}{dt} = y + x - \frac{x^3}{3};\ \frac{dy}{dx} = -x$ for four initial conditions x(0) = 0, y(0) = -1, -2, -3, -4. Plot x vs y for each of the four initial conditions on the same screen for $0 \leq t \leq 15$ The differential equation describing the motion of a pendulum is $\frac{d^2\vartheta}{dt^2} = -sin(\vartheta)$. The pendulum is released from rest at an angular displacement α, i.e. $\vartheta(0) = \alpha$ and $\vartheta'(0) = 0$. Solve the equation for α= 0.1, 0.5 and 1.0 and plot ϑ as a function of time in the range $0 \leq t \leq 8\pi$. Also plot the analytic solution valid for small $\vartheta\left(sin(\vartheta)\right) = \vartheta$

Referred Books:

- Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
- Schaum's Outline of Programming with C++. J. Hubbard, 2000, McGraw-Hill Pub.
- Numerical Recipes in C++: The Art of Scientific Computing, W.H. Pressetal., 3rd Edn., 2007, Cambridge University Press.
- A first course in Numerical Methods, U.M. Ascher & C. Greif, 2012, PHI Learning.
- Elementary Numerical Analysis, K.E. Atkinson, 3 rd E d n . ,2 00 7 ,Wiley IndiaEdition.
- Numerical Methods for Scientists & Engineers, R.W. Hamming, 1973, Courier Dover Pub.
- An Introduction to computational Physics, T. Pang, 2nd Edn., 2006,Cambridge Univ. Press

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GEC-VIII & DSEC-IV: SOLID STATE PHYSICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Prerequisites: Knowledge of "Elements of Modern Physics"

Crystal Structure: Solids: Amorphous and Crystalline Materials. Lattice TranslationVectors. Lattice with a Basis – Central and Non-Central Elements. Unit Cell. Miller Indices. Reciprocal

Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor. **(12 Lectures)**

Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Monoatomicand Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law **(10 Lectures)**

Magnetic Properties of Matter: Dia-, Para-, Ferri- and Ferromagnetic Materials.Classical Langevin Theory of dia – and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss. **(12 Lectures)**

Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom.Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons. **(10 Lectures)**

Elementary band theory: Kronig Pennymodel. Band Gaps. Conductors, Semiconductors and insulators. P and N type Semiconductors. Conductivity of Semiconductors, mobility, Hall Effect, Hall coefficient. **(10 Lectures)**

Superconductivity: Experimental Results. Critical Temperature. Critical magneticfield. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. **(6 Lectures)**

Reference Books:

- Introduction to Solid State Physics, Charles Kittel, 8th Ed., 2004, Wiley India Pvt. Ltd.
- Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India
- Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
- Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning

- Solid State Physics, Rita John, 2014, McGraw Hill
- Solid-state Physics, H. Ibach and H. Luth, 2009, Springer
- Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
- Solid State Physics, M.A. Wahab, 2011, Narosa Publications

GEC-VIII & DSEC-IV - LAB: SOLID STATE PHYSICS
60 Lectures

1. Measurement of susceptibility of paramagnetic solution (Quinck`s Tube Method)
2. To measure the Magnetic susceptibility of Solids.
3. To determine the Coupling Coefficient of a Piezoelectric crystal.
4. To measure the Dielectric Constant of a dielectric Materials with frequency
5. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR)
6. To determine the refractive index of a dielectric layer using SPR
7. To study the PE Hysteresis loop of a Ferroelectric Crystal.
8. To study the BH curve of iron using a Solenoid and determine the energy loss.
9. To measure the resistivity of a semiconductor (Ge) crystal with temperature by four-probe method (room temperature to 150 ^{o}C) and to determine its band gap.
10. To determine the Hall coefficient of a semiconductor sample.

Reference Books:

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.

- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Edn., 2011, Kitab Mahal
- Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India

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GEC-IX & DSEC-V: QUANTUM MECHANICS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Prerequisites: Knowledge of (1) "Mathematical Physics" and (2) "Elements of Modern Physics"

Time dependent Schrodinger equation : Time dependent Schrodinger equation anddynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearityand Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum & Energy operators; commutator of position and momentum operators; Expectation values of position and momentum. Wave Function of a Free Particle. **(6 Lectures)**

Time independent Schrodinger equation-Hamiltonian, stationary states and energyeigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to the spread of Gaussian wavepacket for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction; Position-momentum uncertainty principle. **(10 Lectures)**

General discussion of bound states in an arbitrary potential- continuity of wavefunction, boundary condition and emergence of discrete energy levels; application to one-dimensional problem- square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method. **(12 Lectures)**

Quantum theory of hydrogen-like atoms: time independent Schrodinger equation inspherical polar coordinates; separation of variables for the second order partial differential equation; angular momentum operator and quantum numbers; Radial wavefunctions from Frobenius method; Orbital angular momentum quantum numbers l and m; s, p, d,.. shells (idea only)

(10 Lectures)

Atoms in Electric and Magnetic Fields:- Electron Angular Momentum. Space Quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-

Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment & Magnetic Energy, Gyromagnetic Ratio & Bohr Magneton. **(8 Lectures)**

Atoms in External Magnetic Fields: Normal and Anomalous Zeeman Effect. **(4 Lectures)**

Many electron atoms: Pauli's Exclusion Principle. Symmetric and Antisymmetric Wave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total Angular Momentum. Vector Model. Spin-orbit coupling in atoms-L-S and J-J couplings. **(10 Lectures)**

Reference Books:

- A Text book of Quantum Mechanics, P.M. Mathews & K. Venkatesan, 2nd Ed., 2010, McGraw Hill
- Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
- Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
- Quantum Mechanics, G. Aruldhas, 2nd Edn. 2002, PHI Learning of India.
- Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.
- Quantum Mechanics for Scientists and Engineers, D.A.B. Miller, 2008, Cambridge University Press

Additional Books for Reference

- Quantum Mechanics, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.
- Introduction to Quantum Mechanics, David J. Griffith, 2nd Ed. 2005, Pearson Education
- Quantum Mechanics, Walter Greiner, 4th Edn., 2001, Springer

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GEC-IX & DSEC-V LAB: QUANTUM MECHANICS

60 Lectures

Use C/C^{++}/Scilab for solving the following problems based on Qu~~antum~~ Mechanics like

1. Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom:

   $\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$ where $V(r) = -\frac{e^2}{r}$

Here, m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take e = 3.795 $(eVÅ)^{1/2}$, ħc = 1973 (eVÅ) and m = 0.511×10^6 eV/c^2.

2. Solve the s-wave radial Schrodinger equation for an atom:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

where m is the reduced mass of the system (which can be chosen to be the mass of an electron), for the screened coulomb potential $V(r) = -\frac{e^2}{r}e^{-r/a}$

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take e = 3.795 $(eVÅ)^{1/2}$, m = 0.511×10^6 eV/c^2, and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973 (eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

3. Solve the s-wave radial Schrodinger equation for a particle of mass m:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

For the anharmonic oscillator potential $V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$

for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose m = 940 MeV/c^2, k = 100MeV fm^{-2}, b = 0, 10, 30 MeV fm^{-3} In these units, cħ = 197.3 MeV fm. The ground state energy I expected to lie between 90 and 110 MeV for all three cases.

5. Solve the s-wave radial Schrodinger equation for the vibrations of hydrogen molecule:

$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2\mu}{\hbar^2}[V(r) - E]$Where μ is the reduced mass of the two-atom system for the Morse potential $V(r) = D\left(e^{-2\alpha r'} - e^{-\alpha r'}\right), r' = \frac{r - r_0}{r}$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.

Take: m = 940×10^6 eV/C^2, D = 0.755501 eV, α = 1.44, r_o = 0.131349 Å

Some laboratory based experiments:

5. Study of Electron spin resonance- determine magnetic field as a function of the resonance frequency
6. Study of Zeeman effect: with external magnetic field; Hyperfine splitting
7. To study the quantum tunnelling effect with solid state device, e.g. tunnelling current in backward diode or tunnel diode.

Reference Books:

- Schaum's Outline of Programming with C++. J.Hubbard, 2000, McGraw-Hill Pub.

- Numerical Recipes in C: The Art of Scientific Computing, W.H. Pressetal., 3rd Edn., 2007, Cambridge University Press.
- Elementary Numerical Analysis, K.E. Atkinson, 3rd Ed. 2007, Wiley India Edition
- A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific
- Engineering Applications: A.V. Wouwer, P. Saucez, C.V. Fernández. 2014 Springer
- Scilab by example: M. Affouf, 2012, ISBN: 978-1479203444
- Scilab (A Free Software to Matlab): H. Ramchandran, A.S. Nair. 2011 S. Chandand Company, New Delhi ISBN: 978-8121939706
- Scilab Image Processing: Lambert M. Surhone. 2010Betascript Publishing ISBN: 978-6133459274A
- Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
- Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.

GEC-X & DSEC-VI: EMBEDDED SYSTEM: INTRODUCTION TO MICROCONTROLLERS
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Embedded system introduction: Introduction to embedded systems and generalpurpose computer systems, architecture of embedded system, classifications, applications and purpose of embedded systems, challenges and design issues in embedded systems, operational and non-operational quality attributes of embedded systems, elemental description of embedded processors and microcontrollers. **(6 Lectures)**

Review of microprocessors: Organization of Microprocessor based system, 8085μppin diagram and architecture, concept of data bus and address bus, 8085 programming model, instruction classification, subroutines, stacks and its implementation, delay subroutines, hardware and software interrupts. **(4 Lectures)**

8051 microcontroller: Introduction and block diagram of 8051 microcontroller,architecture of 8051, overview of 8051 family, 8051 assembly language programming, Program Counter and ROM memory map, Data types and directives, Flag bits and Program Status Word (PSW) register, Jump, loop and call instructions. **(12 Lectures)**

8051 I/O port programming: Introduction of I/O port programming, pin out diagramof8051 microcontroller, I/O port pins description and their functions, I/O port programming in 8051, (Using Assembly Language), I/O programming: Bitmanipulation. **(4 Lectures)**

Programming of 8051: 8051addressing modes and accessing memory using variousaddressing modes, assembly language instructions using each addressing mode, arithmetic & logic instructions, 8051 programming in C:- for time delay and I/O operations and manipulation, for arithmetic & logic operations, for ASCII and BCD conversions. **(12 Lectures)**

Timer & counter programming: Programming 8051 timers, counter programming. **(3 Lectures)**

Serial port programming with and without interrupt: Introduction to 8051interrupts, programming timer interrupts, programming external hardware interrupts and serial communication interrupt, interrupt priority in the 8051. **(6 Lectures)**

Interfacing 8051 microcontroller to peripherals: Parallel and serial ADC, DAC interfacing, LCD interfacing. **(2 Lectures)**

Programming Embedded Systems: Structure of embedded program, infinite loop, compiling, linking and locating, downloading and debugging. **(3 Lectures)**

Embedded system design and development: Embedded system development environment, file types generated after cross compilation, disassembler/ decompiler, simulator, emulator and debugging, embedded product development life-cycle, trends in embedded industry. **(8 Lectures)**

Reference Books:

- Embedded Systems: Architecture, Programming & Design, R. Kamal, 2008,Tata McGraw Hill
- The 8051 Microcontroller and Embedded Systems Using Assembly and C, M.A. Mazidi, J.G. Mazidi, and R.D. McKinlay, 2nd Ed., 2007, Pearson Education India.
- Embedded microcomputor system: Real time interfacing, J.W.Valvano, 2000, Brooks/Cole
- Embedded Systems and Robots, Subrata Ghoshal, 2009, Cengage Learning
- Introduction to embedded system, K.V. Shibu, 1st Edition, 2009, McGraw Hill
- Microcontrollers in practice, I. Susnea and M. Mitescu, 2005, Springer.
- Embedded Systems: Design & applications, S.F. Barrett, 2008, Pearson Education
- Embedded Microcomputer systems: Real time interfacing, J.W. Valvano 2011,Cengage Learning

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PRACTICALS- GEC-X & DSEC-VI LAB: EMBEDDED SYSTEM: INTRODUCTION TO MICROCONTROLLERS
60 Lectures

Following experiments using 8051:

1. To find that the given numbers is prime or not.
2. To find the factorial of a number.
3. Write a program to make the two numbers equal by increasing the smallest number and decreasing the largest number.
4. Use one of the four ports of 8051 for O/P interfaced to eight LED's. Simulate binary counter (8 bit) on LED's .
5. Program to glow the first four LEDs then next four using TIMER application.
6. Program to rotate the contents of the accumulator first right and then left.
7. Program to run a countdown from 9-0 in the seven segment LED display.
8. To interface seven segment LED display with 8051 microcontroller and display 'HELP' in the seven segment LED display.
9. To toggle '1234' as '1324' in the seven segment LED display.
10. Interface stepper motor with 8051 and write a program to move the motor through a given angle in clock wise or counter clockwise direction.
11. Application of embedded systems: Temperature measurement, some information on LCD display, interfacing a keyboard.

Reference Books:

- Embedded Systems: Architecture, Programming & Design, R. Kamal, 2008, Tata McGraw Hill
- The 8051 Microcontroller and Embedded Systems Using Assembly and C, M.A. Mazidi, J.G. Mazidi, and R.D. McKinlay, 2nd Ed., 2007, Pearson Education
- Embedded Microcomputor System: Real Time Interfacing, J.W. Valvano, 2000, Brooks/Cole
- Embedded System, B.K. Rao, 2011, PHI Learning Pvt. Ltd.

- Embedded Microcomputer systems: Real time interfacing, J.W. Valvano 2011, Cengage Learning

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GEC-XI & DSEC-VII: Nuclear and Particle Physics
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures
Prerequisites: Knowledge of "Elements of Modern Physics"

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states. **(10 Lectures)**

Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basicassumption of shell model, concept of mean field, residual interaction, concept of nuclear force. **(12 Lectures)**

Radioactivity decay:(a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion. **(10 Lectures)**

Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions,Q-value, reaction rate, reaction cross section, Concept of compound and direct reaction, resonance reaction, Coulomb scattering(Rutherford scattering). **(8 Lectures)**

Interaction of Nuclear Radiation with matter: Energy loss due to ionization (Bethe- Block formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter. **(8 Lectures)**

Detector for Nuclear Radiations: Gas detectors: estimation of electric field,mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.

(8 Lectures)

Particle Accelerators: Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons. **(5 Lectures)**

Particle physics: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons. **(14 Lectures)**

Reference Books:

- Introductory nuclear Physics by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
- Concepts of nuclear physics by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).
- Introduction to the physics of nuclei & particles, R.A. Dunlap. (Thomson Asia, 2004)
- Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
- Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi
- Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde (IOP- Institute of Physics Publishing, 2004).
- Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
- Theoretical Nuclear Physics, J.M. Blatt & V.F.Weisskopf (Dover Pub.Inc., 1991)

DSEC-VIII: Medical Physics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

PHYSICS OF THE BODY-I

Basic Anatomical Terminology: Standard Anatomical Position, Planes. Familiarity with terms like- Superior, Inferior, Anterior, Posterior, Medial, Lateral, Proximal and Distal. **Mechanics of the body:** Skeleton, forces, and body stability. Muscles and dynamics ofbody movement. Physics of Locomotors Systems: joints and movements, Stability and Equilibrium. **Energy household of the body:** Energy balance in the body, Energy consumption of the body, Heat losses of the body, Thermal Regulation. **Pressuresystem of body:** Physics of breathing, Physics of cardiovascular system. **(8 Lectures)**

PHYSICS OF THE BODY-II

Acoustics of the body: Nature and characteristics of sound, Production of speech, Physics of the ear, Diagnostics with sound and ultrasound. **Optical system of the body:** Physics of the eye. **Electrical system of the body:** Physics of the nervous system, Electrical signals and information transfer. **(10 Lectures)**

PHYSICS OF DIAGNOSTIC AND THERAPEUTIC SYSTEMS-I X-RAYS: Electromagnetic spectrum, production of x-rays, x-ray spectra, Brehmsstrahlung, Characteristic x-ray. **X-ray tubes & types**: Coolidge tube, x-ray tube design, tube cooling stationary mode, Rotating anode x-ray tube, Tube rating, quality and intensity of x-ray. X-ray generator circuits, half wave and full wave rectification, filament circuit, kilo voltage circuit. Single and three phase electric supply. Power ratings. Types of X-Ray Generator, high frequency generator, exposure timers and switches, HT cables. **(7 Lectures)**

RADIATION PHYSICS: Radiation units exposure, absorbed dose, units: rad, gray,relative biological effectiveness, effective dose- Rem & Sievert, inverse square law. Interaction of radiation with matter Compton & photoelectric effect, linear attenuation coefficient. **Radiation Detectors**: ionization (Thimble chamber, condenser chamber), chamber. Geiger Muller counter, Scintillation counters and Solid State detectors, TFT. **(7 Lectures)**

MEDICAL IMAGING PHYSICS: Evolution of Medical Imaging, X-ray diagnosticsand imaging, Physics of nuclear magnetic resonance (NMR), NMR imaging, MRI Radiological imaging, Ultrasound imaging, Physics of Doppler with applications and modes, Vascular Doppler. Radiography: Filters, grids, cassette, X-ray film, film processing, fluoroscopy. **Computed tomography scanner**- principle and function, display, generations, mammography. Thyroid uptake system and Gamma camera (Only Principle, function and display). **(9 Lectures)**

RADIATION ONCOLOGY PHYSICS: External Beam Therapy (Basic Idea):Telecobalt, Conformal Radiation Therapy (CRT), 3DCRT, IMRT, Image Guided Radiotherapy, EPID, Rapid Arc, Proton Therapy, Gamma Knife, Cyber Knife. Contact Beam Therapy (Basic Idea): Brachytherapy- LDR and HDR, Intra Operative Brachytherapy. Radiotherapy, kilo voltage machines, deep therapy machines, Telecobalt machines, Medical linear accelerator. Basics of Teletherapy units, deep X-ray, Telecobalt units, Radiation protection, external beam characteristics, dose maximum and build up – bolus, percentage depth dose, tissue maximum ratio and tissue phantom ratio, Planned target Volume and Gross Tumour Volume. **(9 Lectures)**

RADIATION AND RADIATION PROTECTION: Principles of radiation protection,protective materials-radiation effects, somatic, genetic stochastic and deterministic effect. Personal monitoring devices: TLD film badge, pocket dosimeter, OSL dosimeter. Radiation dosimeter. Natural radioactivity, Biological effects of radiation, Radiation monitors**.** Steps to reduce radiation to Patient, Staff and Public. Dose Limits for Occupational workers and Public. AERB: Existence and Purpose. **(5 Lectures)**

PHYSICS OF DIAGNOSTIC AND THERAPEUTIC SYSTEMS-II

Diagnostic nuclear medicine: Radiopharmaceuticals for radioisotope imaging, Radioisotope imaging equipment, Single photon and positron emission tomography. Therapeutic nuclear medicine: Interaction between radiation and matter Dose and isodose in radiation treatment. Medical Instrumentation: Basic Ideas of Endoscope and Cautery, Sleep Apnea and Cpap Machines, Ventilator and its modes. **(5 Lectures)**

Reference Books:

- Medical Physics, J.R. Cameron and J.G.Skofronick, Wiley (1978)
- Basic Radiological Physics Dr. K. Thayalan - Jayapee Brothers Medical Publishing Pvt. Ltd. New Delhi (2003)
- Christensen’s Physics of Diagnostic Radiology: Curry, Dowdey and Murry - Lippincot Williams and Wilkins (1990)
- Physics of the human body, Irving P. Herman, Springer (2007).
- Physics of Radiation Therapy : F M Khan - Williams and Wilkins, 3rd edition (2003)

- The essential physics of Medical Imaging: Bushberg, Seibert, Leidholdt and Boone Lippincot Williams and Wilkins, Second Edition (2002)
- Handbook of Physics in Diagnostic Imaging: R.S.Livingstone: B.I. Publication Pvt Ltd.
- The Physics of Radiology-H E Johns and Cunningham.

PHYSICS-DSEC-VIII LAB: Medical Physics

61 Lectures

1. Understanding the working of a manual Hg Blood Pressure monitor and measure the Blood Pressure.
2. Understanding the working of a manual optical eye-testing machine and to learn eye-testing procedure.
3. Correction of Myopia (short sightedness) using a combination of lenses on an optical bench/breadboard.
4. Correction of Hypermetropia/Hyperopia (long sightedness) using a combination of lenses on an optical bench/breadboard.
5. To learn working of Thermoluminescent dosimeter (TLD) badges and measure the background radiation.
6. Familiarization with Geiger-Muller (GM) Counter and to measure background radiation.
7. Familiarization with Radiation meter and to measure background radiation.
8. Familiarization with the Use of a Vascular Doppler.

Reference Books:

- Basic Radiological Physics, Dr. K. Thayalan - Jayapee Brothers Medical Publishing Pvt. Ltd. New Delhi (2003)
- Christensen's Physics of Diagnostic Radiology: Curry, Dowdey and Murry - Lippincot Williams and Wilkins (1990)
- Physics of Radiation Therapy : F M Khan - Williams and Wilkins, 3rd edition (2003)
- The essential physics of Medical Imaging: Bushberg, Seibert, Leidholdt and Boone Lippincot Williams and Wilkins, Second Edition (2002)
- Handbook of Physics in Diagnostic Imaging: Roshan S. Livingstone: B. I. Publications Pvt Ltd.

- The Physics of Radiology-H E Johns and Cunningham.

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7. Teaching Learning Processes

The teaching learning processes play the most important role in achieving the desired aims and objectives of the undergraduate programs in Physics as elaborated in detail in the learning based curriculum framework (LOCF). Physics is basically an experimental science as any ideas and concepts, no matter how simple, complex or far-fetched have to be tested in the laboratory by performing specific experiments designed to test, validate and confirm them before they are accepted as principles of Physics applicable to natural phenomenon. While such ideas and concepts originate in the minds of the genius, anywhere and anytime in the universe, their verifications and confirmations have to be done in the laboratory established in the real world and executed by competent and well trained scientists and engineers. To achieve this goal, the appropriate training of young individuals to become competent scientists and engineers in future have to be accomplished. For this purpose a very good undergraduate program in Physics and other sciences is the first step. We should therefore have an excellent teaching-learning procedural protocol for all the colleges, universities and other higher education institutions (HEI). To be specific, it is desirable to have:

- Necessary and sufficient infrastructural facilities for the class rooms, laboratories and libraries equipped with adequate modern and modular furnitures and other requirements.
- Modern and updated laboratory equipments needed for the undergraduate laboratories and reference and text books for the libraries.
- Sufficient infrastructure for ICT and other facilities needed for technology-enabled learning like computer facilities, PCs, laptops, Wi-Fi and internet facilities with all the necessary softwares.
- Sufficient number of teachers in permanent position to do all the class room teaching and perform and supervise the laboratory experiments to be done by the students.
- All the teachers should be qualified as per the UGC norms and should have good communication skills.
- Sufficient number of technical and other support staff to run the laboratories, libraries, equipment and maintain the infrastructural facilities like buildings, electricity, sanitation,

cleanliness etc.

- Teachers should make use of all the approaches for an efficient teaching-learning process i.e. :

i). Class room teachings with lectures using traditional as well as electronic boards.

ii). Use of Smart class rooms for simulation and demonstration for conveying the difficult concepts of Physics in class room teaching and laboratories.

iii). Tutorials must be an integral part of all the theory and laboratory courses. Theory courses should have 1-2 tutorials every week depending upon the nature of the course.

iv). Teaching should be complimented with students seminar to be organized very frequently.

v). Guest lectures and seminars should be arranged by eminent teachers to be invited by the concerned college/university/HEI.

vi). Open-ended project work should be given to all students individually or in group to 2-3 students depending upon the nature of the course.

vii). Internship of duration varying from one week anytime in the semester and/or 2-6 weeks during semester break and summer breaks should be arranged by the college/universities/HEI for the students to visit other colleges/universities/HEI and industrial organizations in the vicinity. If needed, financial assistance may also be provided for such arrangements to be made for their internship in the National Laboratories in the region of the institutions.

viii). Special attempts should be made by the institution to develop problem-solving skills and design of laboratory experiments for demonstration at the UG level. For this purpose a mentor system may be evolved where 3-4 students may be assigned to each faculty member.

ix). Teaching load should be managed such that the teacher has enough time to interact with the students to encourage an interactive/participative learning.

8. Assessment Methods

In the undergraduate education of Physics leading to the B. Sc with Physics and Physics (Honours) degree, the assessment and evaluation methods focus on testing the conceptual understanding of the basic ideas, development of mathematical skills and experimental techniques retention and ability to apply the knowledge acquired to explain with analysis and reason what has been learnt and to solve new problems and communicate the results and findings effectively. Since the Learning Objectives are defined clearly for each course in detail, it is easier to design methods to monitor the progress in achieving the learning Objectives during the course and test the level of achievement at the end of the course.

- The courses offered in the undergraduate Physics are the first courses at the college/university level, the priority should be given to Formative Assessment for monitoring the progress towards achieving the Learning Objectives while keeping its weightages lower than Summative Assessments. This is to assure that the students know their strengths and weaknesses periodically through the results of Formative Assessments and make amends for the gaps in their knowledge without affecting their final grades in any significant way. In this context it is suggested that 25-30% weightage be given Formative Assessments in case of theory components while 30-40% weightage be given to the Laboratory/Field work/Projects/Case Study/Dissertation components of the various courses. Moreover use of more than one method of Assessment in each course is highly recommended.
- Some of the methods suggested for Theory Component with regard to Formative Assessment are i) Regular Tutorial assignments ii) seminar presentations iii).Performance in group discussions iv) Problem based longer assignments (other than tutorials) v) True/False Tests vi) Multiple Choice Tests vii) Short Answer Tests viii) viva-voce tests ix) Any other innovative tests in the context of the course.
- In the case of substantive Summative Assessment for the theory papers, can be a combination of the following i) Mid -Semester test ii) Seminar Report iii) Individual /Team Project report iv) Oral Presentations of Seminar/Projects v) Viva -Voce Examination on the above reports vi .End Semester closed book examination in the pattern of a) Multiple Choice b) Short Answer c) Long Answer vii) End Semester

Open Book Examination viii) Peer examination by a group of experts a) Written b) Oral ix) Any other innovative method depending upon the nature of the course.

- B. Laboratory Experiments / Field work / Projects / Case Study / Dissertation can be assessed for Formative Assessment through i) Regular evaluation of Lab. experiments regarding a) written report of each experiment b) Viva-Voce on each experiment ii) Test through setting experiments by assembling components iii) Mid semester examination iv)Design innovative kits to test the comprehension and analysis of the experiment done by the students
- At the end, the main purpose of Physics teaching should be to impart objective knowledge to students in concrete, comprehensive and effective way. Here, effectiveness implies gaining knowledge and skill which can be applied to solve practical problems as well as attaining capability of logical thinking and imagination which are conducive to new knowledge and new discoveries. Once the student learns, 'why is it worth learning?' and 'how does it connect to the real world?' The student shall embrace the curriculum in a way which would incite imagination and imbibe a spirit of enquiry in them, so that in future they will opt for further investigations or research. Needless to say, there should be a continuous evaluation system for the students. This will enable the teachers not only to ascertain the overall progress of learning by the students, but also to identify the students who are slow learner and for whom special care should be taken. An appropriate grading system is the 'relative grading system' can also be envisaged for certain papers, introducing a competitive element among the students. All in all, the teacher should act as a facilitator and guide and not as a guardian of curriculum.
- HEI can design their own ways and methods to quantify the assessment and evaluation based on the above methods It would then be converted to the letter grades by the procedure described by the template given by the UGC.
- Once the letter grade for a course is obtained for a course, it should be done for all the courses offered by the student. Once the letter grades for all the grades are accumulated then a CGPA should be calculated by quantifying the letter grades as described by the template provided by the UGC.

9. Key Words

Ability Enhancement Compulsory Course (AECC)

Course Learning Outcomes (CLO)

Discipline Specific Electives (DSE)

Formative Assessment (FA)

Generic Elective Courses (GEC)

Learning Outcome based on Curriculum Frame work (LOCF)

Learning Outcomes, Program Learning Outcomes (PLO)

Skill Enhancement Courses (SEC)

Student Centric, Teacher Centric

Teaching Learning Methodology

Expert Committee Members of Learning Outcomes based Curriculum Framework (LOCF) Physics

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Prof A C Pandey, Director IUAC, Aruna Asaf Ali Marg, New Delhi

Learning Outcomes based Curriculum Framework (LOCF)

for

Computer Science

Undergraduate B.Sc./B.Sc.(Hons) Programmes

2020

ज्ञान-विज्ञान विमुक्तये

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.

DPSingh

(Prof. D. P. Singh)
Chairman
University Grants Commission

New Delhi
30th July, 2019

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Preamble

Education is the key to development of any society. Role of higher education is crucial for securing right kind of employment and also to pursue further studies in best available world class institutes elsewhere within and outside India. Quality education in general and higher education in particular deserves high priority to enable the young and future generation of students to acquire skill, training and knowledge in order to enhance their thinking, creativity, comprehension and application abilities and prepare them to compete, succeed and excel globally. Sustained initiatives are required to reform the present higher education system for improving and upgrading the academic resources and learning environments by raising the quality of teaching and standards of achievements in learning outcomes across all undergraduate programs in science, humanities, commerce and professional streams of higher education including computer science. One of the significant reforms in the undergraduate education is to introduce the Learning Outcomes-based Curriculum Framework (LOCF) which makes it student-centric, interactive and outcome-oriented with well-defined aims, objectives and goals to achieve. LOCF also aims at ensuring uniform education standard and content delivery across the country which will help the students to ensure similar quality of education irrespective of the institute and location. With initiatives of University Grants Commission (UGC) for nation-wide adoption and implementation of the LOCF for bachelor's programmes in colleges, universities and HEIs in general. A Core Expert Committee (CEC) was constituted to formulate the modalities for developing the LOCF in various subjects being taught in the undergraduate courses in sciences, humanities, commerce and professional courses. The CEC also constituted the Subject Expert Committees (SEC) in various subjects to prepare detailed guidelines for the LOCF in subjects concerned.

The Learning Outcomes (LO) specified by the CEC are the guidelines to determine the structure of the undergraduate programs to be offered by the Higher Educational Institutions (HEI) of our country. The key components of the planning and development of LOCF are given in terms of clear and unambiguous description of the Graduate Attributes (GA), Qualification Descriptors (QD), Program Learning Outcomes (PLO) and Course Learning Outcomes (CLO) to be achieved at the end of the successful completion of each undergraduate program to be offered by HEIs. In undergraduate education in Computer Science, there are two programmes of study leading to the degree of B.Sc. with Computer Science and B.Sc(Hons) in Computer Science. Several meetings were held by the SEC to formulate the framework for both undergraduate programmes. In the first meeting of the Committee, held in UGC on …, the Chairman of SEC briefed the members about the decisions taken in the meeting of chairpersons of all SECs with the members of CEC and officers of UGC. He appraised the members the task at hand and the modalities to prepare the report were elucidated. The topics were allocated to each member keeping in mind the members' expertise and interests. It was proposed that the prepared notes shall be circulated among all members for feedback in the first instance. The committee after getting first set of inputs met again at University of Hyderabad on October 8, 2018 where different course outcomes, course objectives, learning outcomes, core structures of the programme were discussed. Chairman also informed that UGC also wants detailed syllabus of each course. Accordingly, each member was advised to prepare the syllabus along with textbooks, reference books and circulate among the members for inputs. Subsequently, in another meeting again held at University of Hyderabad, the detailed syllabus was discussed and finalized incorporating the suggestions of members. The Qualification Descriptors (QD), Program Learning Outcomes (PLO) and the Course Learning Outcomes (CLO) were also finalized keeping the broad requirement of the programme in view. The LOCF also gives general guidelines for the Teaching Learning Process (TLP) corresponding to each component of theory, experiment, tutorials, projects and industrial / field visits to be followed in order to achieve the stated outcomes for each component. Finally, some suggestions for using various methods in the assessment and evaluation of learning levels of students are also made.

The main objective of this whole exercise is to prepare a comprehensive course structure with detailed syllabus along with quality reading material in order to have a uniform standard of education in undergraduate Computer Science programme in the country. This document shall serve as a model document across the higher education institutes (HEIs) in the country for teachers, students and academic administrators. It is a student centric framework where they are expected to learn fundamentals of computer science along with the latest trends and techniques like Artificial Intelligence, Internet of Things, Machine Intelligence alongwith advanced skillsets that include Mobile Application Development, Object Oriented Programming among many other courses.

We sincerely hope that our sincere effort in this endeavor will help the students to be equipped with fundamental as well as advanced and latest technologies in computer science after completion of the programme irrespective of the location and institute across the length and breadth of the country. This will also prepare to opt for higher education in top notch universities and institutes within and outside India. We thank UGC and other experts who contributed in our endeavor.

1. Introduction

Computer Science (CS) has been evolving as an important branch of science and engineering throughout the world in last couple of decades and it has carved out a space for itself like any other disciplines of basic science and engineering. Computer science is a discipline that spans theory and practice and it requires thinking both in abstract terms and in concrete terms. Nowadays, practically everyone is a computer user, and many people are even computer programmers. Computer Science can be seen on a higher level, as a science of problem solving and problem solving requires precision, creativity, and careful reasoning. The ever-evolving discipline of computer science also has strong connections to other disciplines. Many problems in science, engineering, health care, business, and other areas can be solved effectively with computers, but finding a solution requires both computer science expertise and knowledge of the particular application domain.

Computer science has a wide range of specialties. These include Computer Architecture, Software Systems, Graphics, Artificial Intelligence, Computational Science, and Software Engineering. Drawing from a common core of computer science knowledge, each specialty area focuses on specific challenges. Computer Science is practised by mathematicians, scientists and engineers. Mathematics, the origins of Computer Science, provides reason and logic. Science provides the methodology for learning and refinement. Engineering provides the techniques for building hardware and software.

Universities and other HEIs introduced programmes of studies in computer science as this discipline evolved itself to a multidisciplinary discipline. Information Technology is growing rapidly. Increasing applications of computers in almost all areas of human endeavour has led to vibrant industries with concurrent rapid change in technology. Unlike other basic disciplines, developing core competency in this discipline that can be reasonably stable becomes a challenge. In India, it was initially introduced at the Master (postgraduate) level as MCA and M.Tech. Later on, engineering programmes such as B.Tech and B.E in Computer Science & Engineering and in Information Technology were introduced in various engineering College/Institutions to cater to the growing demand for trained engineering manpower in IT industries. Parallelly, BSc and MSc programmes with specialisation in Computer Science were introduced to train manpower in this highly demanding area. B.Sc and B.Sc(Hons) in Computer Science are being planned and introduced in different colleges and institutions.

Computer Science education at undergraduate level (+3) will result in earning a Bachelor of Arts (BA) or Bachelor of Science (BS) degree in CS. The coursework required to earn a BSc is equally weighted in mathematics and science. B.Sc with CS and BSc(Hons) in CS are aimed at undergraduate level training facilitating multiple career paths. Students so graduated, can take up postgraduate programmes in CS leading to research as well as R&D, can be employable at IT industries, or can pursue a teachers' training programme such BEd in Computer Education, or can adopt a business management career. BSc with CS aims at laying a strong foundation of CS at an early stage of the career along with two other subjects such as Physics, Maths, Electronics, Statistics etc. There are several employment opportunities and after successful completion of an undergraduate programme in CS, graduating students can fetch employment directly in companies as Web Developer, Software Engineer, Network Administrator, Data Scientist, or AI/ML personnel.

The Learning Outcome-based Curriculum Framework in Computer Science is aimed at allowing flexibility and innovation in design and development of course content, in method of imparting training, in teaching learning process and in assessment procedures of the learning outcomes. The emphasis in computer science courses, in outcome-based curriculum framework, help students learn solving problems, accomplishing IT tasks, and expressing creativity, both individually and collaboratively. The proposed framework will help Students learn programming techniques and the syntax of one or more programming languages.

Many of the learning outcomes of Computer Science can be achieved only by programming a computer for several different meaningful purposes. All students must, therefore, have access to a computer with a modern programming language installed. The computer science framework does not prescribe a specific language. The teacher and students will decide which modern programming languages students will learn. More importantly, students will learn to adapt to changes in programming languages and learn new languages as they are developed.

The present Learning Outcome-based Curriculum Framework for bachelor's degrees in CS is intended to facilitate the students to achieve the following.

- To develop an understanding and knowledge of the basic theory of Computer Science and Information Technology with good foundation on theory, systems and applications such as algorithms, data structures, data handling, data communication and computation.
- To develop the ability to use this knowledge to analyse new situations
- To acquire necessary and state-of-the-art skills to take up industry challenges. The objectives and outcomes are carefully designed to suit to the above-mentioned purpose.
- The ability to synthesize the acquired knowledge, understanding and experience for a better and improved comprehension of the real-life problems
- To learn skills and tools like mathematics, statistics, physics and electronics to find the solution, interpret the results and make predictions for the future developments.

2. Curriculum Planning- Learning Outcomes-based Approach

2.1 Nature and Extent of the B.Sc/B.Sc. (Hons.) Programme

The undergraduate programs in Computer Science builds on science-based education at +2 level. The +2 senior secondary school education aims and achieves a sound grounding in understanding the basic scientific temper with introduction to process of computation by introducing some programming languages. This prepares a young mind to launch a rigorous investigation of exciting world of computer science.

Framing and implementation of curricula and syllabi is envisaged to provide an understanding of the basic connection between theory and experiment and its importance in understanding the foundation of computing. This is very critical in developing a scientific temperament and to venture a career which a wide spectrum of applications as well as theoretical investigations. The undergraduate curriculum provides students with theoretical foundations and practical experience in both hardware and software aspects of computers. The curriculum in computer science is integrated with courses in the sciences and the humanities to offer an education that is broad, yet of enough depth and relevance to enhance student employment opportunities upon graduation. As a Bachelor's degree program, the curriculum is based on the criterion that graduates are expected to function successfully in a professional employment environment immediately upon graduation.

The undergraduate program in Computer Science is presently being offered though the courses designed for granting the following degrees by various colleges and universities in India. All the courses are of 3-year duration spread over six semesters.

i. B.Sc (Honours) Computer Science

ii. B.Sc with Computer Science

B. Sc. with Computer Science

B.Sc. or Bachelor of Science with Computer Science is a general multidiscipline bachelor programme. The programme has a balanced emphasis on three science subjects, one of which is computer science. A student studying B.Sc. with Computer Science is required to choose two other subjects from a pool of subjects which include Physics, Mathematics, Statistics, Electronics, Chemistry. Different institutions offer different choice of combinations of subjects. Most popular combinations are Physics and Mathematics, Physics and Electronics, Mathematics and Electronics, but there are also combinations like Statistics and Economics or Commerce and Economics alongwith Computer Science.

B.Sc.(Hons) in Computer Science

B.Sc. (Hons) in India is generally a three-year degree program which develops advanced theoretical and research skills in subject in which Honours is opted. It is a specialized programme offering specialization in one science subject and another auxiliary science subject. This programme helps in building an advanced professional or academic career. It is an appropriate course for students who wish to pursue a Master of Science (M.Sc) or Doctor of Philosophy (PhD) and a research or academic career. This program facilitates students who wish to pursue an independent research project in an area of interest under the supervision of an academic. B.Sc.(Hons) differs from BSc in the number of courses in the subject in which Honours is opted. Thus BSc(Hons) has more CS courses than that of BSc programme.

B.Sc. with CS and B.Sc. (Hons) in CS follow CBCS structure as mandated by UGC. In accordance with CBCS guidelines the courses are categorized into compulsory courses, elective courses, ability enhancement courses. These categories of courses are discussed below keeping the present context of undergraduate education in CS in mind.

2.2 Types of Courses

2.2.1 Core Course (CC)

A core course is a mandatory course required in degree. **Core course** of study refers to a series or selection of courses that all students are required to complete before they can move on to the next level in their education or earn a diploma. The general educational purpose of a core course of study is to ensure that all students take and complete courses that are academically and culturally essential. These are the courses that teach students the foundational knowledge and skills they will need in securing the specific degree or diploma. The core courses are designed with an aim to cover the basics that is expected of a student to imbibe in that particular discipline. Thus, a course, which should compulsorily be studied by a candidate as a core requirement is termed as a Core course. The present document specifies the core courses for B.Sc. The courses (papers, as referred popularly) under this category are going to be taught uniformly across all universities with 30% deviation proposed in the draft. The purpose of fixing core papers is to ensure that all the institutions follow a minimum common curriculum so that each institution/ university adheres to common minimum standard.

2.2.2 Electives

Generally a course which can be chosen from a pool of courses and which may be very specific or specialized or advanced or supportive to the discipline/ subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate's proficiency/skill is called an Elective Course. Different types of elective courses mandated in the present framework are the following.

- Domain Specific Elective (DSE)
- Generic Elective (GE)
- Ability Enhancement Elective (AEEC)

2.2.3 Discipline Specific Elective (DSE)

Elective courses offered under the main discipline/subject of study is referred to as Discipline Specific Elective. The list provided under this category are suggestive in nature and HEI has freedom to suggest its own papers under this category based on their expertise, specialization, requirements, scope and need. The University/Institute may also offer discipline related elective courses of interdisciplinary nature (to be offered by main discipline/subject of study).

2.2.4 Generic Elective (GE)

An elective course chosen from another discipline/subject, with an intention to seek exposure beyond discipline/s of choice is called a Generic Elective. The purpose of this category of papers is to offer the students the option to explore disciplines of interest beyond the choices they make in Core and Discipline Specific Elective papers. The list provided under this category are suggestive in nature and HEI can design its own papers under this category based on available expertise, specialization, and contextual requirements, scope and need.

P.S.: A core course offered in a discipline/subject may be treated as an elective by other discipline/subject and vice versa and such electives may also be referred to as Generic Elective.

GE for B.Sc. Honours- ONE auxiliary discipline of interest other than major subject in which Honours is opted from a set of related science disciplines is chosen for the entire 3-year and Generic Elective (GE) are opted one paper for each semester in the chosen discipline only.

2.2.5 Dissertation/Project

An elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate studies such a course on his/her own with an advisory support by a teacher/faculty member is called dissertation/project.

2.2.6 Ability Enhancement Courses (AEC)

The Ability Enhancement Courses may be of two kinds:

A. **Ability Enhancement Compulsory Courses (AECC):** AECC are the courses based upon the content that leads to knowledge enhancement. These are mandatory for all disciplines. Ability Enhancement Compulsory Courses (AECC) are the following.

- AECC-I English
- AECC-II English/Hindi/ MIL Communications
- AECC-III Environment Science

B. Skill Enhancement Courses (SEC): SEC courses are value-based and/or skill-based and are aimed at providing hands-on-training, competencies, skills, etc. SEC are at least 2 courses for Honours courses and 4 courses for General bachelor programmes. These courses may be chosen from a pool of courses designed to provide value-based and/or skill-based knowledge and should contain both theory and lab/hands-on/training/field work. The main purpose of these courses is to provide students life-skills in hands-on mode to increase their employability. The list provided under this category are suggestive in nature and each university has freedom to suggest their own papers under this category based on their expertise, specialization, requirements, scope and need.

2.2.7 Practical/Tutorial

For each core course and DSE course there will be one practical. The list of practical provided is suggestive in nature and each university has the freedom to add/subtract/edit practical from the list depending on their faculty and infrastructure available. Addition will however be of similar nature.

2.3 Aims of Bachelor of Science Programmes in Computer Science

The Bachelor of Science degree in Computer Science emphasizes problem solving in the context of algorithm development and software implementation and prepares students for effectively using modern computer systems in various applications. The curriculu m provides required computer science courses such as programming languages, data structures, computer architecture and organization, algorithms, database systems, operating systems, and software engineering; as well as elective courses in artificial intelligence, computer-based communication networks, distributed computing, information security, graphics, human-computer interaction, multimedia, scientific computing, web technology, and other current topics in computer science. The main aim of this Bachelor’s degree is to deliver a modern curriculum that will equip graduates with strong theoretical and practical backgrounds to enable them to excel in the workplace and to be lifelong learners. The purpose of the BS programs in computer science are twofold: (1) to prepare the student for a position involving the design, development and implementation of computer software/hardware, and (2) to prepare the student for entry into a program of postgraduate study in computer science/engineering and related fields.

The Bachelor of Science program with Computer Science as one subject (BSc with CS) and the Bachelor of Science Honours programme in Computer Science (BSc(Hons) in CS) focus on the concepts and techniques used in the design and development of software systems. Students in this program explore the conceptual underpinnings of Computer Science -- its fundamental algorithms, programming languages, operating systems, and software engineering techniques. In addition, students choose from a rich set of electives that includes data science, computer graphics, artificial intelligence, database systems, computer architecture, and computer networks, among other topics. A generous allotment of free electives allows students to combine study in computer science with study in auxiliary fields to formulate a program that combines experiences across disciplines.

3. Graduate Attributes

Graduate Attributes (GA) are the qualities, skills and understandings that students should develop during their time with the HEI. These are qualities that also prepare graduates as agents of social good in future. Graduate Attributes can be viewed as qualities in following subcategories.

- Knowledge of the discipline
- Creativity
- Intellectual Rigour
- Problem Solving and Design
- Ethical Practices
- Lifelong Learning
- Communication and Social Skills

Among these attributes, categories attributes under *Knowledge of the Discipline* are specific to a programme of study.

3.1.a. Knowledge of Discipline of CS

Knowledge of a discipline is defined as "command of a discipline to enable a smooth transition and contribution to professional and community settings. This Graduate Attribute describes the capability of demonstrating comprehensive and considered knowledge of a discipline. It enables students to evaluate and utilise information and apply their disciplinary knowledge and their professional skills in the workplace.

3.1.b. Creativity

Creativity is a skill that underpins most activities, although this may be less obvious in some disciplines. Students are required to apply imaginative and reflective thinking to their studies. Students are encouraged to look at the design or issue through differing and novel perspectives. Creativity allows the possibility of a powerful shift in outlook and enables students to be open to thinking about different concepts and ideas.

3.1.c. Intellectual Rigour

Intellectual Rigour is the commitment to excellence in all scholarly and intellectual activities, including critical judgement. The students are expected in having clarity in thinking. This capability involves engaging constructively and methodically when exploring ideas, theories and philosophies. It also relates to the ability to analyse and construct knowledge with depth, insight and intellectual maturity.

3.1.d. Problem Solving and Design

Problem solving skills empower students not only within the context of their programmes, but also in their personal and professional lives. Many employers cite good problem solving skills as a desired attribute that they would like graduates to bring to the workplace. With an ability to seek out and identify problems, effective problem solvers are able to actively engage with a situation, think creatively, to consider different perspectives to address identified challenge, to try out possible solutions and subsequently evaluate results as a way to make decisions. Through this process they can consolidate new and emergent knowledge and develop a deeper understanding of their subject discipline.

3.1.e. Ethical Practices

Ethical practice is a key component of professionalism and needs to be instilled in curricula across courses. When operating ethically, graduates are aware that we live in a diverse society with many competing points of view. Ethical behaviour involves tolerance and responsibility. It includes being open-minded about cultural diversity, linguistic difference, and the complex nature of our world. It also means behaving appropriately towards colleagues and the community and being sensitive to local and global social justice issues.

3.1.f. Life-Long Learning

The skill of being a lifelong learner means a graduate is open, curious, willing to investigate, and consider new knowledge and ways of thinking. This flexibility of mind means they are always amenable to new ideas and actively seek out new ways of learning or understanding the world.

3.1.g. Communication and Social Skills

The ability to communicate clearly and to work well in a team setting is critical to sustained and successful employment. Good communication and social skills involve the ability to listen to, as well as clearly express, information back to others in a variety of ways - oral, written, and visual - using a range of technologies.

3.1.h. Self-Management

Graduates must have capabilities for self-organisation, self-review, personal development and life-long learning.

3.2 LIST OF GRADUATE ATTRIBUTES for B.Sc. and B.Sc.(Hons)

Afore-mentioned GAs can be summarized in the following manner.

GA 1. A commitment to excellence in all scholarly and intellectual activities, including critical judgement

GA 2. Ability to think carefully, deeply and with rigour when faced with new knowledge and arguments.

GA 3. Ability to engage constructively and methodically when exploring ideas, theories and philosophies

GA 4. Ability to consider other points of view and make a thoughtful argument

GA 5. Ability to develop creative and effective responses to intellectual, professional and social challenges

GA 6. Ability to apply imaginative and reflective thinking to their studies

GA 7. Commitment to sustainability and high ethical standards in social and professional practices.

GA 8. To be open-minded about cultural diversity, linguistic difference, and the complex nature of our world

GA 9. Ability to be responsive to change, to be inquiring and reflective in practice, through information literacy and autonomous, self-managed learning.

GA 10. Ability to communicate and collaborate with individuals, and within teams, in professional and community settings

GA 11. Ability to communicates effectively, comprehending and writing effective reports and design documentation, summarizing information, making effective oral presentations and giving and receiving clear oral instructions

GA 12. Ability to demonstrates competence in the practical art of computing in by showing in design an understanding of the practical methods, and using modern design tools competently for complex real-life IT problems

GA 13. Ability to use a range of programming languages and tools to develop computer programs and systems that are effective solutions to problems.

GA 14. Ability to understand, design, and analyse precise specifications of algorithms, procedures, and interaction behaviour.

GA 15. Ability to apply mathematics, logic, and statistics to the design, development, and analysis of software systems

GA 16. Ability to be equipped with a range of fundamental principles of Computer Science that will provide the basis for future learning and enable them to adapt to the constant rapid development of the field.

GA 17. Ability of working in teams to build software systems.

GA 18. Ability to identify and to apply relevant problem-solving methodologies

GA 19. Ability to design components, systems and/or processes to meet required specifications

GA 20. Ability to synthesise alternative/innovative solutions, concepts and procedures

GA 21. Ability to apply decision making methodologies to evaluate solutions for efficiency, effectiveness and sustainability

GA 22. A capacity for self-reflection and a willingness to engage in self-appraisal

GA 23. Open to objective and constructive feedback from supervisors and peers

GA 24. Able to negotiate difficult social situations, defuse conflict and engage positively in purposeful debate.

4. Qualification Descriptors

Qualification descriptors are generic statements of the outcomes of study. Qualification descriptors are in two parts. The first part is a statement of outcomes, achievement of which a student should be able to demonstrate for the award of the qualification. This part will be of interest to those designing, approving and reviewing academic programmes. They will need to be satisfied that, for any programme, the curriculum and assessments provide all students with the opportunity to achieve, and to demonstrat e achievement of, the outcomes. The second part is a statement of the wider abilities that the typical student could be expected to have developed. It will be of assistance to employers and others with an interest in the general capabilities of holders of the qualification. The framework has the flexibility to accommodate diversity and innovation, and to accommodate new qualifications as the need for them arises. It should be regarded as a framework, not as a straitjacket.

4.1. Qualification Descriptor for B.Sc. with CS

On completion of B.Sc. with Computer Science, the expected learning outcomes that a student should be able to demonstrate are the following.

QD-1. Fundamental understanding of the principles of Computer Science and its connections with other disciplines

QD-2. Procedural knowledge that creates different types of professionals related to Computer Science, including research and development, teaching and industry, government and public service;

QD-3. Skills and tools in areas related to computer science and current developments in the academic field of study.

QD-4. Use knowledge, understanding and skills required for identifying problems and issues, collection of relevant quantitative and/or qualitative data drawing on a wide range of sources, and their application, analysis and evaluation using methodologies as appropriate to Computer Science for formulating solutions

QD-5. Communicate the results of studies undertaken in Computer Science accurately in a range of different contexts using the main concepts, constructs and techniques

QD-6. Meet one’s own learning needs, drawing on a range of current research and development work and professional materials

QD-7. Apply Computer Science knowledge and transferable skills to new/unfamiliar contexts,

QD-8. Demonstrate subject-related and transferable skills that are relevant to industry and employment opportunities.

4.2. Qualification Descriptors for BSc(Hons) in Computer Science

On completion of B.Sc (Hons) in Computer Science, the expected learning outcomes that a student should be able to demonstrate

QD-Hons 1. A systematic, extensive and coherent knowledge and understanding of the field of computer science as a whole and its applications, and links to related disciplinary areas; including a critical understanding of the established theories, principles and concepts, and of a number of advanced and emerging issues in the field of Computer Science

QD-Hons 2. Procedural knowledge that creates different types of professionals related to Computer Science, including research and development, teaching industry and government and public service;

QD-Hons 3. Skills in areas related to computer science and usage of tools and current developments, including a critical understanding of the latest developments in the area, and an ability to use established techniques of analysis and enquiry within the area of Computer Science.

QD-Hons 4. Demonstrate comprehensive knowledge, including current research, scholarly, and/or professional literature, relating to essential and advanced learning areas pertaining to the chosen disciplinary areas (s) and field of study, and techniques and skills required for identifying problems and issues relating to the disciplinary area and field of study.

QD-Hons 5. Demonstrate skills in identifying information needs, collection of relevant quantitative and/or qualitative data drawing on a wide range of sources, effective analysis and interpretation of data

QD-Hons 6. Use knowledge, understanding and skills for critical assessment of a wide range of ideas and complex problems and issues relating to the chosen field of study.

QD-Hons 7. Communicate the results of studies accurately in a range of different contexts using the main concepts, constructs and techniques of the subject(s) of study;

QD-Hons 8. Address one’s own learning needs relating to current and emerging areas of study, making use of research, development and professional materials as appropriate

QD-Hons 9. Apply one’s disciplinary knowledge and transferable skills to new/unfamiliar contexts and to identify and analyse problems and issues and seek solutions to real-life problems.

QD-Hons 10. Demonstrate subject-related and transferable skills that are relevant to industry and employment opportunities.

5. Programme Learning Outcomes

These outcomes describe what students are expected to know and be able to do by the time of graduation. They relate to the skills, knowledge, and behaviours that students acquire in their graduation through the program

5.1. Programme Learning Outcomes for BSc with CS

The Bachelor of Science with Computer Science (BSc with CS) program enables students to attain, by the time of graduation:

PLO-A. Demonstrate the aptitude of Computer Programming and Computer based problem solving skills.

PLO-B. Display the knowledge of appropriate theory, practices and tools for the specification, design, implementation

PLO-C. Ability to learn and acquire knowledge through online courses available at different MOOC Providers.

PLO-D. Ability to link knowledge of Computer Science with other two chosen auxiliary disciplines of study.

PLO-E. Display ethical code of conduct in usage of Internet and Cyber systems.

PLO-F. Ability to pursue higher studies of specialization and to take up technical employment.

PLO-G. Ability to formulate, to model, to design solutions, procedure and to use software tools to solve real world problems and evaluate .

PLO-H. Ability to operate, manage, deploy, configure computer network, hardware, software operation of an organization.

PLO-I. Ability to present result using different presentation tools.

PLO-J. Ability to appreciate emerging technologies and tools.

5.2. Additional PLOs for B.Sc. (Hons) in CS

The Bachelor of Science Honours in Computer Science (B.Sc. (Hons) in CS) program enables students to attain following additional attributes besides the afore-mentioned attributes, by the time of graduation:

PLO-K. Apply standard Software Engineering practices and strategies in real-time software project development

PLO-L. Design and develop computer programs/computer -based systems in the areas related to algorithms, networking, web design, cloud computing, IoT and data analytics.

PLO-M. Acquaint with the contemporary trends in industrial/research settings and thereby innovate novel solutions to existing problems

PLO-N. The ability to apply the knowledge and understanding noted above to the analysis of a given information handling problem.

PLO-O. The ability to work independently on a substantial software project and as an effective team member.

6. Course Structures

6.1 Structure of B.Sc. with CS

The B.Sc. programme with CS as one of the subjects consists of 132 credits in accordance with the Choice Based Credit System (CBCS) approved by the UGC with 1 weekly -contact-hour for each credit for theory/tutorials and 2 weekly-contact-hours for each credit of laboratory work.

6.1.1. Credit-wise Distribution - Out of 132 credits, 108 credits are equally divided among CS (denoted as A in the following table) and two other auxiliary subjects, denoted as B and C, (36 credits each). 36 credits for each subject are further distributed as 24 credits for Core Compulsory Courses (CC) and 12 credits for Discipline Specific Electives (DSE). There are 8 credits for Ability Enhancement Compulsory Courses. SEC's will have 16 credits.

6.1.2. Course-wise Distribution - There are 4 CC courses for each subject (CS and two auxiliary subjects). Each CC course is of 6 credits (4 Theory + 2 Practicum). Similarly, there are 2 DSE papers, each of 6 credits. There are 4 Skill Enhancement Courses (SEC) each of 4 credits with a total of 16 credits. 16 credits of SEC are distributed as 8 credits (2 courses) for subject A (CS) and 4 credits for each of two auxiliary subjects, subjects B and C (one courses for each subject). There are two AECC namely, Environ mental Sciences and Languages/ Communications with 4 credits.

6.1.3. Semester-wise Distribution – BSc with CS is a 3-Yr programme with 6 semesters. In each semester, there will be 22 credits. For each of first four semesters, there will be 3 CC, one each for subjects A, B and C accounting to 18 credits. Similarly, for semesters 5 and 6, there will be 3 DSE in each semester and one DSE for each of three subjects (a, B and C). Two AECC will be offered in first two semesters. SEC will be offered in semesters 3, 4, 5 and 6 and a student is required to take any one SEC from a pool of options. However, in semesters 3 and 4, SEC for the auxiliary subjects will be offered and in semesters 5 and 6, SEC for CS will be offered.

The scope of the present proposal is to design CS courses. There are 4 CC courses for CS, 2 DSE courses and 2 SEC (CS related elective). A student can take more than 132 credits in total (but not more than 148 credits) to qualify for the grant of the B.Sc. (CS) degree after completing them successfully as per rules and regulations of the HEI.

Table I presents the structure in a schematic form. Table II gives details of CS papers in each of different course-categories.

6.2 Course Structure of B.Sc (Hons) in Computer Science

The B.Sc. (Hons) in Computer Science programme consists of 148 credits in accordance with UGC's CBCS with 1 contact-hour per week for each credit for Theory/Tutorial and 2 contact-hour per week for each credit for practical.

6.2.1. Credit-wise Distribution – Out of 148 credits in BSc(Hons) in CS, 84 credits of CC papers in CS, 24 credits of GE papers are devoted to one auxiliary subject, DSE paperss are of 24 credits, AECC papers are 8 credits, and SEC papers are of 8 credits.

6.2.2. Course-wise Distribution - In BSc(Hons) in CS, there are 14 core compulsory courses (CC) in CS subjects, each of 6 credits (4+2). There are 4 Discipline Specific Electives (DSE) papers each of 6 (4+2) credits. In addition, there are 2 AEC papers and 2 SEC papers. There are 4 GE papers each of 6 credits. One auxiliary discipline of interest from Mathematics Statistics, Operational Research , Physics, and Electronics for the entire 3-year and Generic Elective (GE) are opted one paper for each semester in the chosen discipline only.

6.2.3. Semester-wise Distribution- Unlike BSC programme, BSc (Hons) programme has uneven distribution of credits in 6 semesters. First two semesters have 22 credits each, third and fourth semesters have 28 credits each and each of fifth and sixth semester has 24 credits.

Table III presents the structure of BSc(Hons) in CS and Table IV lists the CS-specific courses for the programme

.

TABLE I: COURSE STRUCTURE FOR GENERAL B.Sc.

SEMESTER	Compulsory Core Courses (CC) each with 06 credit; 04 Core courses are compulsory for each subject A, B and C	Discipline Specific Elective (DSE) A- for CS; B and C are other subjects	Ability Enhancement Compulsory Courses (AECC)	Skill Enhancement Course (SEC) Select any one in each semester of Sem-III and Sem-IV	Total Credit
Sem- I	CC-1A **CS** CC- 1B *Auxiliary Sub* CC- 1C *Auxiliary Sub*		AECC-1		22
Sem-II	CC-2A **CS** CC-2B *Auxiliary Sub* CC- 2C *Auxiliary Sub*		AECC-2		22
Sem-III	CC-3A **CS** CC- 3B: *Auxiliary Sub* CC- 3C: *Auxiliary Sub*			Any one of the following SEC-1B *Auxiliary* SEC-1C *Auxiliary*	22
Sem-IV	CC-4A **CS** CC- 4B *Auxiliary Sub* CC- 4C *Auxiliary Sub*			Any one of the following SEC-2B *Auxiliary* SEC-2C *Auxiliary*	22
Sem-V		DSE-1A **CS** DSE-1B *Auxiliary* DSE-1C *Auxiliary*		Any one elective of SEC-3A **CS**	22
Sem- VI		DSE-2A **CS** DSE-2B *Auxiliary* DSE-2C *Auxiliary*		Any one elective of SEC-4A **CS**	22

TABLE II: CS COURSE DETAILS FOR GENERAL B.Sc. WITH CS

Course-Type	Course-code as referred above	Compulsory/Elective	List of compulsory courses and list of option of elective courses. (A suggestive list)
CC	CC-1A, CC-2A, CC-3A, CC-4A	Compulsory	Programming Methodologies, AND Data Structure, AND Operating Systems, AND DBMS
DSE	DSE 1A	Elective	Software Engineering, OR Computer Ethics OR Computer Organization & Architecture OR Computer Networks
	DSE 2A	Elective	Data Mining OR Internet of Things OR Artificial Intelligence OR Computer Graphics
SEC	SEC 3A	Elective	MATLAB Programming OR, Programming in Java OR Python Programming
	SEC 4A	Elective	Web Programming OR Mobile Application Development OR Cloud Computing
AEC	AECC1, AECC2	Compulsory	Communication in English, Environmental Science

TABLE III: COURSE STRUCTURE FOR B.Sc. (Hons)

SEM	Core Courses (CC) each with 06 credit. All 14 courses are compulsory	Ability Enhancement Compulsory Courses (AECC) Select any 2 (04 credits each)	Skill Enhancement Course (SEC) Select any 4 courses (04 credits each)	Discipline Specific Elective (DSE) Select any 4 courses (06 credits each)	Generic Elective, 4 courses (06 credits each) in 4 semesters on one auxiliary subject	Total Credit
I	CC-1	AEC-1			GEC-1	22
	CC-2					
II	CC-3	AEC-2			GEC-2	22
	CC-4					
III	CC-5		SEC-1		GEC-3	28
	CC-6					
	CC-7					
IV	CC-8		SEC-2		GEC-4	28
	CC-9					
	CC-10					
V	CC-11			DSE-1		24
	CC-12			DSE-2		
VI	CC-13			DSE-3		24
	CC-14			DSE-4		

TABLE IV: CS COURSE DETAILS FOR B.Sc.(HONS) in CS

<table>
<tr><th>SEM</th><th>Core Courses (CC) each with 06 credit. 14 compulsory courses</th><th>Discipline Specific Electives. 4 courses. One from set of courses in a box</th><th>Skill Enhancement Courses SEC 2 courses</th></tr>
<tr><td rowspan="2">I</td><td>Programming Methodology</td><td></td><td></td></tr>
<tr><td>Computer System Architecture</td><td></td><td></td></tr>
<tr><td rowspan="2">II</td><td>Data Structure</td><td></td><td></td></tr>
<tr><td>Discrete Structures</td><td></td><td></td></tr>
<tr><td rowspan="3">III</td><td>Operating System</td><td></td><td rowspan="3">Any one
MATLAB Programming,
Programming in Java,
Python Programming</td></tr>
<tr><td>Algorithms</td><td></td></tr>
<tr><td>Computer Networks</td><td></td></tr>
<tr><td rowspan="3">IV</td><td>Software Engineering</td><td></td><td rowspan="3">Any one
Mobile Application Dev,
Web Programming,
GIMP(GNU Image Manipulation Program)</td></tr>
<tr><td>DBMS</td><td></td></tr>
<tr><td>Object Oriented Programming</td><td></td></tr>
<tr><td rowspan="2">V</td><td>Internet Technologies</td><td rowspan="2">Any two of (suggestive list)
Image Processing,
Data Analytics,
Computer Ethics,
System Security,
Human Computer Interface,</td><td></td></tr>
<tr><td>Artificial Intelligence</td><td></td></tr>
<tr><td rowspan="2">VI</td><td>Computer Graphics</td><td rowspan="2">Any two of (suggestive list)
Modelling and Simulation,
Theory of Computation,
Data Mining,
Cloud Computing,
Internet of Things ,
Institutions can add courses</td><td></td></tr>
<tr><td>Machine Learning</td><td></td></tr>
</table>

CS as Generic Elective

For B.Sc. (Hons) programme with Honours in subjects such as Physics, Mathematics, Statistics, Electronics etc, CS can be one of the auxiliary subjects. The following table gives the details CS courses as Generic Elective for BSc(Hons) in other subjects.

TABLE V: CS COURSE DETAILS AS GEC FOR B.Sc.(HONS) in OTHER SUBJECT

SEM	Generic Elective Courses (GEC) each with 06 credit. 4 Courses	
I	GEC-I	Programming Methodology
II	GEC-II	Data Structure OR Discrete Structures
III	GEC-III	Operating System OR Algorithms OR Computer Networks
IV	GEC-IV	Software Engineering OR DBMS OR Object Oriented Programming

6.3 Course Learning Outcomes, Contents, References

PROGRAMMING METHODOLOGY

1. Learn to develop simple algorithms and flow charts to solve a problem.
2. Develop problem solving skills coupled with top down design principles.
3. Learn about the strategies of writing efficient and well-structured computer algorithms/programs.
4. Develop the skills for formulating iterative solutions to a problem.
5. Learn array processing algorithms coupled with iterative methods.
6. Learn text and string processing efficient algorithms.
7. Learn searching techniques and use of pointers.
8. Understand recursive techniques in programming.

SYLLABUS

A. Theory **4 credits**

UNIT I. Introduction to Programming, Program Concept, Characteristics of Programming, Stages in Program Development, Algorithms, Notations, Design, Flowcharts, Types of Programming Methodologies, Introduction to C++ Programming - Basic Program Structure In C++, Variables and Assignments, Input and Output, Selection and Repetition Statements.

UNIT II. Top-Down Design, Predefined Functions, Programmer -defined Function, Local Variable, Function Overloading, Functions with Default Arguments, Call-By-Value and Call-By-Reference Parameters, Recursion.

UNIT III. Introduction to Arrays, Declaration and Referring Arrays, Arrays in Memory, Initializing Arrays. Arrays in Functions, Multi-Dimensional Arrays.

UNIT IV. Structures - Member Accessing, Pointers to Structures, Structures and Functions, Arrays of Structures, Unions.

UNIT V. Declaration and Initialization, Reading and Writing Strings, Arrays of Strings, String and Function, Strings and Structure, Standard String Library Functions.

UNIT VI. Searching Algorithms - Linear Search, Binary Search. Use of files for data input and output. merging and copy files.

TEXT AND REFERENCE BOOKS

- Problem Solving and Program Design in C, J. R. Hanly and E. B. Koffman, Pearson, 2015.
- Programming and problem solving with C++: brief edition, N. Dale and C. Weems, Jones & Bartlett Learning, 2010.

B. Practicum **2 Credits**

Given the problem statement, students are required to formulate problem, develop flowchart/algorithm, write code, execute and test it. Students should be given assignments on following :

a. To learn elementary techniques involving arithmetic operators and mathematical expressions, appropriate use of selection (if, switch, conditional operators) and control structures

b. Learn how to use functions and parameter passing in functions, writing recursive programs.

2. Write Programs to learn the use of strings and string handling operations.
   a. Problems which can effectively demonstrate use of Arrays. Structures and Union.
   b. Write programs using pointers.
   c. Write programs to use files for data input and output.
   d. Write programs to implement search algorithms.

COMPUTER SYSTEM ARCHITECTURE

1. To make students understand the basic structure, operation and characteristics of digital computer.
2. To familiarize the students with arithmetic and logic unit as well as the concept of the concept of pipelining.
3. To familiarize the students with hierarchical memory system including cache memories and virtual memory.
4. To make students know the different ways of communicating with I/O devices and standard I/Ointerfaces.

SYLLABUS **6 credits**

UNIT I Fundamentals of Digital Electronics: Data Types, Complements, Fixed-Point Representation, Floating-Point Representation, Other Binary Codes, Error Detection Codes, Logic Gates, Boolean Algebra, Map Simplification, Combinational Circuits, Flip-Flops, Sequential Circuits, Registers, Counters, Multiplexer, Demultiplexer, Decoder, Encoder.

UNIT II Register Transfer and Micro operations: Register Transfer Language, Register Transfer, Bus & Memory Transfer, Arithmetic Microoperations, Logic Microoperations, Shift Microoperation.

UNIT III Basic Computer Organization: Instruction codes, Computer Registers, Computer Instructions, Timing & Control, Instruction Cycles, Memory Reference Instruction, Input-Output & Interrupts, Complete Computer Description & Design of Basic Computer.

UNIT IV Processor and Control Unit: Hardwired vs. Micro programmed Control Unit, General Register Organization, Stack Organization, Instruction Format, Data Transfer & Manipulation, Program Control, RISC, CISC, Pipelining – Pipelined datapath and control – Handling Data hazards & Control hazards.

UNIT V Memory and I/O Systems: Peripheral Devices, I/O Interface, Data Transfer Schemes, Program Control, Interrupt, DMA Transfer, I/O Processor. Memory Hierarchy, Processor vs. Memory Speed, High-Speed Memories, Cache Memory, Associative Memory, Interleave, Virtual Memory, Memory Management.

UNIT VI Parallelism: Instruction-level-parallelism – Parallel processing challenges – Flynn's classification – Hardware multithreading – Multicore processors

TEXT BOOKS

- Computer System Architecture, M. Morris Mano, 3rd Edition, Prentice Hall.
- Computer Organization and Design, David A. Patterson and John L. Hennessey, Fifth edition, Morgan Kauffman / Elsevier, 2014.

REFERENCE BOOKS

- Computer Architecture: A Quantitative Approach, John L. Hennessy, David A. Patterson, 4th Edition.
- Computer Organization and Architecture, William Stallings, Prentice Hall.

DATA STRUCTURES

1. To be familiar with fundamental data structures and with the manner in which these data structures can best be implemented; become accustomed to the description of algorithms in both functional and procedural styles
2. To have a knowledge of complexity of basic operations like insert, delete, search on these data structures.
3. Ability to choose a data structure to suitably model any data used in computer applications.
4. Design programs using various data structures including hash tables, Binary and general search trees, heaps, graphs etc.
5. Ability to assess efficiency tradeoffs among different data structure implementations.
6. Implement and know the applications of algorithms for sorting, pattern matching etc.

SYLLABUS

A. Theory **4 credits**

UNIT I. Basic concepts- Algorithm Specification-Introduction, Recursive algorithms, Data Abstraction Performance analysis, Linear and Non Linear data structures, Singly Linked Lists-Operations, Concatenating, circularly linked lists-Operations for Circularly linked lists, Doubly Linked Lists- Operations. Representation of single, two dimensional arrays, sparse matrices-array and linked representations.

UNIT II. Stack- Operations, Array and Linked Implementations, Applications- Infix to Postfix Conversion, Postfix Expression Evaluation, Recursion Implementation, Queue- Definition and Operations, Array and Linked Implementations, Circular Queues - Insertion and Deletion Operations, Dequeue (Double Ended Queue).

UNIT III. Trees, Representation of Trees, Binary tree, Properties of Binary Trees, Binary Tree Representations- Array and Linked Representations, Binary Tree Traversals, Threaded Binary Trees, Priority Queue- Implementation, Heap- Definition, Insertion, Deletion.

UNIT IV. Graphs, Graph ADT, Graph Representations, Graph Traversals, Searching, Static Hashing- Introduction, Hash tables, Hash functions, Overflow Handling.

UNIT V. Sorting Methods, Comparison of Sorting Methods, Search Trees- Binary Search Trees, AVL Trees- Definition and Examples.

UNIT VI. Red-Black and Splay Trees, Comparison of Search Trees, Pattern Matching Algorithm- The Knuth-Morris-Pratt Algorithm, Tries (examples).

TEXTBOOKS

- Fundamentals of Data structures in C, 2nd Edition, E. Horowitz, S. Sahni and Susan Anderson-Freed, Universities Press.

- Data structures and Algorithm Analysis in C, 2nd edition, M. A. Weiss, Pearson.
- Lipschutz: Schaum's outline series Data structures Tata McGraw-Hill

B. Practicum **2 credits**

Students are required to write and practically execute programs to solve problem using various data structures. The teacher can suitably device problems which help students experiment using the suitable datastructures and operations. Some of the problems are indicated below.

1. Write program that uses functions to perform the following:

    a) Creation of list of elements where the size of the list, elements to be inserted and deleted are dynamically given as input.

    b) Implement the operations, insertion, deletion at a given position in the list and search for an element in the list

    c) To display the elements in forward / reverse order

2. Write a program that demonstrates the application of stack operations (Eg: infix expression to postfix conversion)

3. Write a program to implement queue data structure and basic operations on it (Insertion, deletion, find length) and code atleast one application using queues.

4. Write a program that uses well defined functions to Create a binary tree of elements and Traverse the a Binary tree in preorder, inorder and postorder,

5. Write program that implements linear and binary search methods of searching for an elements in a list

6. . Write and trace programs to understand the various phases of sorting elements using the methods

    a) Insertion Sort

    b) Quicksort

    c) Bubble sort

7. Write and trace programs to Create a Binary search tree and insert and delete from the tree.

8. Represent suitably a graph data structure and demonstrate operations of travesrals on it.

DISCRETE STRUCTURES

1. Understand the notion of mathematical thinking, mathematical proofs, and algorithmic thinking, and be able to apply them in problem solving.
2. Understand the basics of combinatorics, and be able to apply the methods from these subjects in problem solving.
3. Be able to use effectively algebraic techniques to analyse basic discrete structures and algorithms.
4. Understand asymptotic notation, its significance, and be able to use it to analyse asymptotic performance for some basic algorithmic examples.
5. Understand some basic properties of graphs and related discrete structures, and be able to relate these to practical examples.

SYLLABUS **6 credits**

UNIT I. Sets: Finite and Infinite Sets, Uncountable Infinite Sets; Functions, Relations, Properties of Binary Relations, Closure, Partial Ordering Relations; Counting - Pigeonhole Principle, Permutation and Combination; Mathematical Induction, Principle of Inclusion and Exclusion.

UNIT II. Growth of Functions: Asymptotic Notations, Summation Formulas and Properties, Bounding Summations, Approximation by Integrals

UNIT III. Recurrences: Recurrence Relations, Generating Functions, Linear Recurrence Relations with Constant Coefficients and their Solution, Substitution Method, Recurrence Trees, Master Theorem

UNIT IV. Graph Theory: Basic Terminology, Models and Types, Multigraphs and Weighted Graphs, Graph Representation, Graph Isomorphism, Connectivity, Euler and Hamiltonian Paths and Circuits, Planar Graphs, Graph Coloring, Trees, Basic Terminology and Properties of Trees, Introduction to Spanning Trees

UNIT V. Propositional Logic: Logical Connectives, Well-formed Formulas, Tautologies, Equivalences, Inference Theory

REFERENCE BOOKS

- C.L. Liu & Mahopatra, Elements of Discrete mathematics, 2nd Sub Edition 1985, Tata McGraw Hill
- Rosen, Discrete Mathematics and Its Applications, Sixth Edition 2006
- T.H. Coremen, C.E. Leiserson, R. L. Rivest, Introduction to algorithms, Prentice Hall on India (3rd edition 2009)
- M. O. Albertson and J. P. Hutchinson, Discrete Mathematics with Algorithms 1988 John wiley Publication

OPERATING SYSTEM

1. Describe the important computer system resources and the role of operating system in their management policies and algorithms.
2. To understand various functions, structures and history of operating systems and should be able to specify objectives of modern operating systems and describe how operating systems have evolved over time.
3. Understanding of design issues associated with operating systems.
4. Understand various process management concepts including scheduling, synchronization, and deadlocks.
5. To have a basic knowledge about multithreading.
6. To understand concepts of memory management including virtual memory.
7. To understand issues related to file system interface and implementation, disk management.
8. To understand and identify potential threats to operating systems and the security features design to guard against them.
9. To have sound knowledge of various types of operating systems including Unix and Android.
10. Describe the functions of a contemporary operating system with respect to convenience, efficiency, and the ability to evolve.

SYLLABUS **6 credits**

UNIT I. (Introduction to Operating System) What is Operating System? History and Evolution of OS, Basic OS functions, Resource Abstraction, Types of Operating Systems– Multiprogramming Systems, Batch Systems, Time Sharing Systems; Operating Systems for Personal Computers, Workstations and Hand-held Devices, Process Control & Real time Systems.

UNIT II. (Operating System Organization and Process Characterization) Processor and User Modes, Kernels, System Calls and System Programs, System View of the Process and Resources, Process Abstraction, Process Hierarchy, Threads, Threading Issues, Thread Libraries; Process Scheduling, Non-Pre-emptive and Pre-emptive Scheduling Algorithms.

UNIT III. Process Management (Deadlock) Deadlock, Deadlock Characterization, Necessary and Sufficient Conditions for Deadlock, Deadlock Handling Approaches: Deadlock Prevention, Deadlock Avoidance and Deadlock Detection and Recovery.

UNIT IV. (Inter Process Communication and Synchronization) Concurrent and Dependent Processes, Critical Section, Semaphores, Methods for Inter-process Communication; Process Synchronization, Classical Process Synchronization Problems: Producer-Consumer, Reader-Writer.

UNIT V. (Memory Management) Physical and Virtual Address Space; Memory Allocation Strategies– Fixed and -Variable Partitions, Paging, Segmentation, Virtual Memory.

UNIT VI. (File and I/O Management, OS security) Directory Structure, File Operations, File Allocation Methods, Device Management, Pipes, Buffer, Shared Memory, Security Policy Mechanism, Protection, Authentication and Internal Access Authorization

UNIT VII. (Introduction to Android Operating System) Introduction to Android Operating System, Android Development Framework, Android Application Architecture, Android Process Management and File System, Small Application Development using Android Development Framework.

REFERENCE BOOKS

- A Silberschatz, P.B. Galvin, G. Gagne, Operating Systems Concepts, 8th Edition, John Wiley Publications 2008.
- A.S. Tanenbaum, Modern Operating Systems, 3rd Edition, Pearson Education 2007.
- G. Nutt, Operating Systems: A Modern Perspective, 2nd Edition Pearson Education 1997.
- W. Stallings, Operating Systems, Internals & Design Principles 2008 5th Edition, Prentice Hall of India.
- M. Milenkovic, Operating Systems- Concepts and design, Tata McGraw Hill 1992.

ALGORITHMS

1. To learn good principles of algorithm design;
2. To learn how to analyse algorithms and estimate their worst-case and average-case behaviour (in easy cases);
3. To become familiar with fundamental data structures and with the manner in which these data structures can best be implemented; become accustomed to the description of algorithms in both functional and procedural styles;
4. To learn how to apply their theoretical knowledge in practice (via the practical component of the course).

SYLLABUS

A Theory **4 Credits**

UNIT I. Introduction: Basic Design and Analysis Techniques of Algorithms, Correctness of Algorithm. Algorithm Design Techniques: Iterative Techniques, Divide and Conquer, Dynamic Programming, Greedy Algorithms.

UNIT II. Sorting and Searching Techniques: Elementary Sorting techniques– Bubble Sort, Insertion Sort, Merge Sort, Advanced Sorting techniques- Heap Sort, Quick Sort, Sorting in Linear Time - Bucket Sort, Radix Sort and Count Sort, Searching Techniques- Medians & Order Statistics, complexity analysis

UNIT III. Graphs Algorithms: Graph Algorithms– Breadth First Search, Depth First Search and its Applications, Minimum Spanning Trees. String Processing

UNIT IV. Lower Bounding Techniques: Decision Trees, Balanced Trees, Red-Black Trees

UNIT V. Advanced Analysis Technique: Randomized Algorithm, Distributed Algorithm, Heuristics

RECOMMENDED BOOKS

- T.H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein Introduction to Algorithms, PHI, 3rd Edition 2009
- Sara basse & A.V. Gelder Computer Algorithm – Introduction to Design and Analysis, Publisher – Pearson 3rd Edition 1999

B. Practicum **2 Credits**

The student shall develop programs in a chosen language to solve problems using algorithm design techniques such asDivide and Conquer, Greedy, Dynamic programming and Backtracking. Some of the problems to be solved are indicated below.

1. Write a test program to implement Divide and Conquer Strategy . Eg: Quick sort algorithm for sorting list of integers in ascending order
2. Write a program to implement Merge sort algorithm for sorting a list of integers in ascending order.
3. Write program to implement the DFS and BFS algorithm for a graph.
4. Write program to implement backtracking algorithm for solving problems like N-queens ..
5. Write a program to implement the backtracking algorithm for the sum of subsets problem
6. Write program to implement greedy algorithm for job sequencing with deadlines.
7. Write a program to implement Dijkstra's algorithm for the Single source shortest path problem.
8. Write a program that implements Prim's algorithm to generate minimum cost spanning tree.
9. Write a program that implements Kruskal's algorithm to generate minimum cost spanning tree
10. Write program to implement Dynamic Programming algorithm for the 0/1 Knapsack problem.
11. Write program to implement Dynamic Programming algorithm for the Optimal Binary Search Tree Problem.

COMPUTER NETWORKS

1. Understand the structure of Data Communications System and its components. Be familiarize with different network terminologies.
2. Familiarize with contemporary issues in network technologies.
3. Know the layered model approach explained in OSI and TCP/IP network models
4. Identify different types of network devices and their functions within a network.
5. Learn basic routing mechanisms, IP addressing scheme and internetworking concepts.
6. Familiarize with IP and TCP Internet protocols.
7. To understand major concepts involved in design of WAN, LAN and wireless networks.
8. Learn basics of network configuration and maintenance.
9. Know the fundamentals of network security issues.

SYLLABUS **6 credits**

UNIT I. Introduction to Computer Networks and Networking Elements: Network Definition, Network Topologies, Network Classifications, Network Protocol, Layered Network Architecture, Overview of OSI Reference Model, Overview of TCP/IP Protocol Suite, Hub, Switch (Managed and Unmanaged), Routers

UNIT II. Data Communication Fundamentals and Techniques: Analog and Digital Signal, Data-Rate Limits, Digital to Digital Line Encoding Schemes, Pulse Code Modulation, Parallel and Serial Transmission, Digital to Analog Modulation - Multiplexing Techniques- FDM, TDM, Transmission Media.

UNIT III. Networks Switching Techniques and Access Mechanisms: Circuit Switching, Packet Switching- Connectionless Datagram Switching, Connection-Oriented Virtual Circuit Switching; Dial-Up Modems, Digital Subscriber Line, Cable TV for Data Transfer.

UNIT IV. Data Link Layer Functions and Protocol: Error Detection and Error Correction Techniques, Data-Link Control- Framing and Flow Control, Error Recovery Protocols-Stop and Wait ARQ, Go-Back-N ARQ, Point to Point Protocol on Internet.

UNIT V. Multiple Access Protocol and Network Layer: CSMA/CD Protocols, Ethernet LANS; Connecting LAN and Back-Bone Networks- Repeaters, Hubs, Switches, Bridges, Router and Gateways, Networks Layer Functions and Protocols (6 Lectures) Routing, Routing Algorithms, Network Layer Protocol of Internet - IP Protocol, Internet Control Protocols.

UNIT VI. Transport Layer and Application Layer Functions and Protocols: Transport Services- Error and Flow Control, Connection Establishment and Release- Three Way Handshake, Overview of Application Layer Protocol (5 Lectures) Overvi ew of DNS Protocol; Overview of WWW & HTTP Protocol.

REFERENCE BOOKS

- B. A. Forouzan: Data Communications and Networking, Fourth edition, THM Publishing Company Ltd 2007.
- A. S. Tanenbaum: Computer Networks, Fourth edition, PHI Pvt. Ltd 2002

SOFTWARE ENGINEERING

1. Basic knowledge and understanding of the analysis and design of complex systems.
2. Ability to apply software engineering principles and techniques.
3. To produce efficient, reliable, robust and cost-effective software solutions.
4. Ability to work as an effective member or leader of software engineering teams.
5. To manage time, processes and resources effectively by prioritising competing demands to achieve personal and team goals Identify and analyzes the common threats in each domain.

SYLLABUS **6 credits**

UNIT I. Software Development Approaches: Introduction; Evolving Role of Software; Software Characteristics; Software Applications. Software Design Processes: Introduction; What is Meant by Software Engineering?, Definitions of Software Engineering; The Serial or Linear Sequential Development Model; Iterative Development Model; The incremental Development Model

UNIT II. Software Design Principles: Introduction, System Models: Data-flow Models, Semantic Data Models, Object Models, Inheritance Models, Object Aggregation, Service Usage Models, Data Dictionaries; Software Design: The Design Process, Design Methods, Design description, Design Strategies, Design Quality; Architectural Design: System Structuring, The Repository Model, The Client–Server Model, The Abstract Machine Model, Control Models, Modular Decomposition, Domain-Specific Architectures.

UNIT III. Object Oriented Design: Introduction; Object Oriented Design: Objects, Object Classes & Inheritance, Inheritance, Object Identification, An Object-Oriented Design Example, Object Aggregation; Service Usage; Object Interface Design: Design Evolution, Function Oriented Design, Data–Flow Design; Structural Decomposition: Detailed Design.

UNIT IV. An Assessment of Process Life-Cycle Models: Introduction; Overview of the Assessment of Process; The Dimension of Time; The Need for a Business Model in Software Engineering; Classic Invalid Assumptions: First Assumption: Internal or External Drivers, Second Assumption: Software or Business Processes, Third Assumption: Processes or Projects, Fourth Assumption: Process Centered or Architecture Centered; Implications of the New Business Model; Role of the Problem-Solving Process in this Approach: Data, Problem Definition, Tools and Capabilities; Redefining the Software Engineering Process: Round-Trip Problem-Solving Approach, Activities, Goals, Interdisciplinary Resources, Time.

UNIT V. Software Reliability: Introduction; Software Reliability Metrics; Programming for Reliability: Fault Avoidance, Fault Tolerance, Software Reuse.

UNIT VI. Software Testing Techniques: Introduction; Software Testing Fundamental; Testing Principles; White Box Testing; Control Structure Testing; Black Box Testing; Boundary Value Analysis; Testing GUIs; Testing Documentation and Help Facilities; Software Testing Strategies: Introduction; Organizing for Software

Testing; Software Testing Strategy, Unit Testing: Unit Test Considerations, Top-Down Integration, Bottom-Up Integration.

REFERENCE BOOKS

- R. G. Pressman – Software Engineering, TMH
- Sommerville, Ian, Software Engineering, Pearson Education
- Pankaj Jalote – An Integrated Approach to Software Engineering, Narosa Publications.
- Pfleeger, Shari Lawrence, Software Engineering Theory and Practice, second edition. Prentice- Hall 2001.
- Object Oriented & Classical Software Engineering (Fifth Edition), SCHACH,TMH

DATABASE MANAGEMENT SYSTEMS

1. Gain knowledge of database systems and database management systems software.
2. Ability to model data in applications using conceptual modelling tools such as ER Diagrams and design data base schemas based on the model.
3. Formulate, using SQL, solutions to a broad range of query and data update problems.
4. Demonstrate an understanding of normalization theory and apply such knowledge to the normalization of a database.
5. Be acquainted with the basics of transaction processing and concurrency control.
6. Familiarity with database storage structures and access techniques.
7. Compare, contrast and analyse the various emerging technologies for database systems such as NoSQL.
8. Analyse strengths and weaknesses of the applications of database technologies to various subject areas.

SYLLABUS

A Theory **4 Credits**

UNIT I. Basic Database Concepts, Terminology, and Architecture; Types of Database Management Systems. Differences between Relational and other Database Models. Data Modelling: Relations, Schemas, Constraints, Queries, and Updates; Conceptual vs. Physical Modeling; Entity Types, attributes, ER Diagrams.

UNIT II. SQL Data Definition: Specifying Tables, Data Types, Constraints; Simple SELECT, INSERT, UPDATE, DELETE Statements; Complex SELECT Queries, including Joins and Nested Queries; Actions and Triggers; Views; Altering Schemas.

UNIT III. Relational Algebra: Definition of Algebra; Relations as Sets; Operations: SELECT, PROJECT, JOIN, etc. Normalization Theory and Functional Dependencies, 2NF, 3NF, BCNF, 4NF, 5NF;

UNIT IV. Indexing: Files, Blocks, and Records, Hashing; RAID; Replication; Single-Level and Multi-Level Indexes; B-Trees and B+-Trees. Query Processing Translation of SQL into Query Plans; Basics of Transactions, Concurrency and Recovery.

UNIT V. DATABASE PROGRAMMING: Embedded SQL; Dynamic SQL, JDBC; Avoiding Injection Attacks; Stored Procedures; Lightweight Data Access Layers for Python and JavaScript Applications; PHP and MySQL, Object Relational Modeling: Hibernate for Java, Active Record for Rails.

UNIT VI. BIG DATA: Motivations; OLAP vs. OLTP; Batch Processing; MapReduce and Hadoop; Spark; Other Systems: HBase. Working with POSTGRES, REDIS, MONGO, and NEO: Setting up the same Database on Four Platforms; Basic Queries and Reporting.

TEXTBOOKS

- Elmasri's and Navathe's *Fundamentals of Database Systems*. Addison-Wesley

REFERENCE BOOK

- Data base Management Systems, Raghu Ramakrishnan, Johannes Gehrke, McGraw Hill Education
- Data base System Concepts, A. Silberschatz, Henry. F. Korth, S. Sudarshan, McGraw Hill Education

B. Practicum **2 credits**

Students are required to practice the concepts learnt in the theory by designing and querying a database for a chosen organization (Like Library, Transport etc). The teacher may devise appropriate weekly lab assignments to help students practice the designing , querying a database in the context of example database. Some indicative list of experiments is given below.

Experiment 1: E-R Model

Analyze the organization and identify the entities , attributes and relationships in it. .

Identify the primary keys for all the entities. Identify the other keys like candidate keys, partial keys, if any.

Experiment 2: Concept design with E-R Model

Relate the entities appropriately. Apply cardinalities for each relationship. Identify strong entities and weak entities (if any).

Experiment 3: Relational Model

Represent all the entities (Strong, Weak) in tabular fashion. Represent relation ships in a tabular fashion.

Experiment 4: Normalization

Apply the First, Second and Third Normalization levels on the database designed for the organization

Experiment 5: Installation of Mysql and practicing DDL commands

Installation of MySql. Creating databases, How to create tables, altering the database, dropping tables and databases if not required. Try truncate, rename commands etc.

Experiment 6: Practicing DML commands on the Database created for the example organization

DML commands are used to for managing data within schema objects. Some examples:

- SELECT - retrieve data from the a database
- INSERT - insert data into a table
- UPDATE - updates existing data within a table
- DELETE - deletes all records from a table, the space for the records remain

Experiment 7: Querying

practice queries (along with sub queries) involving ANY, ALL, IN, Exists, NOT EXISTS, UNION, INTERSECT, Constraints etc.

Experiment 8 and Experiment 9: Querying (continued…)

Practice queries using Aggregate functions (COUNT, SUM, AVG, and MAX and MIN),

GROUP BY, HAVING and Creation and dropping of Views.

Experiment 10: Triggers

Work on Triggers. Creation of, insert trigger, delete trigger, update trigger. Practice triggers using the above database.

OBJECT ORIENTED PROGRAMMING

1. Learn the concepts of data, abstraction and encapsulation
2. Be able to write programs using classes and objects, packages.
3. Understand conceptually principles of Inheritance and Polymorphism and their use and program level implementation.
4. Learn exception and basic event handling mechanisms in a program
5. To learn typical object-oriented constructs of specific object oriented programming language

SYLLABUS

A. Theory **4 credits**

UNIT I. Basics: Introduction to Object Oriented Programming and its Basic Features, Basic Components of C++, Characteristics of Object-Oriented Language, Structure of a C++ Program, Flow Control Statements in C++, Functions - Scope of Variables, Inline Functions, Recursive Functions, Pointers to Functions, C++ Pointers, Arrays, Dynamic Memory Allocation and De-Allocation

UNIT II. Differences Between Object Oriented and Procedure Oriented Programming, Abstraction, Overview of Object-Oriented Programming Principles, Encapsulation, C++ Classes, Objects, User Defined Types, Constructors and Destructors, this Pointer, Friend Functions, Data Abstraction, Operator Overloading, Type Conversion

UNIT III. Class Inheritance, Base and Derived Classes, Virtual Base Class, Virtual Functions, Polymorphism, Static and Dynamic Bindings, Base and Derived Class Virtual Functions, Dynamic Binding through Virtual Functions, Pure Virtual Functions, Abstract Classes, Virtual Destructors

UNIT IV. Stream Classes Hierarchy, Stream I/O, File Streams, Overloading the Extraction and Insertion Operators, Error Handling during File Operations, Formatted I/O.

UNIT V. Exception Handling- Benefits of Exception Handling, Throwing an Exception, the Try Block, Catching an Exception, Exception Objects, Exception Specifications, Rethrowing an Exception, Uncaught Exceptions

TEXT BOOKS

- Problem solving with C++: The Object of Programming, Walter Savitch, 4th Edition, Pearson Education.
- C++: The Complete Reference, Herbert Schildt, 4th Edition

REFERENCE BOOKS

- Object Oriented Programming with C++, Sourav Sahay, 2nd Edition, Oxford
- The C++ Programming Language, B. Stroutstrup, 3rd Edition, Pearson Education
- Programming in C++, Ashok N Kamthane. Pearson 2nd Edition

B. Practicum **2 credits**

Students are required to understand the object-oriented concepts using C++. They are required to practice the concepts learnt in the theory . Some of the programs to be implemented are listed as follows:

Part A

1. Number of vowels and number of characters in a string.
2. Write a function called zeros maller () that is passed with two introduce arguments by reference and set the smaller of the number to zero. Write a man() program to access this function.
3. Demonstration of array of object.
4. Using this pointer to return a value (return by reference).
5. Demonstration of virtual function.
6. Demonstration of static function.
7. Accessing a particular record in a student's file.
8. Demonstration of operator overloading.

Part B

9. Write a program to create a database for students that contains Name, Enrolment no, Department, Programme using Constructors, destructors, input and output functions ; input and output for 10 people using different methods.

10. Create a class holding information of the salaries of all the family members (husband, wife, son, daughter). Using friend functions give the total salary of the family.

INTERNET TECHNOLOGIES

1. To understand the terms related to the Internet and how the Internet is changing the world.
2. To understand how computers are connected to the Internet and demonstrate the ability to use the World Wide Web.
3. Demonstrate an understanding of and the ability to use electronic mail and other internet based services
4. Understand the design principles of Web pages and how they are created
5. To develop an ability to create basic Web pages with HTML.

SYLLABUS **6 credits**

UNIT I. Introduction: Overview, Network of Networks, Intranet, Extranet and Internet. World Wide Web, Domain and Sub domain, Address Resolution, DNS, Telnet, FTP, HTTP. Review of TCP/IP: Features, Segment, Three-Way Handshaking, Flow Control, Error Control, Congestion control,

UNIT II. IP Datagram, IPv4 and IPv6. IP Subnetting and addressing: Classful and Classless Addressing, Subnetting. NAT, IP masquerading, IP tables. Internet Routing Protocol: Routing -Intra and Inter Domain Routing, Unicast and Multicast Routing, Broadcast. Electronic Mail: POP3, SMTP.

UNIT III. HTML: Introduction, Editors, Elements, Attributes, Heading, Paragraph. Formatting, Link, Head, Table, List, Block, Layout, CSS. Form, Iframe, Colors, Colorname, Colorvalue. Image Maps: map, area, attributes of image area. Extensible Markup Language (XML): Introduction, Tree, Syntax, Elements, Attributes, Validation, Viewing. XHTML in brief. CGI Scripts: Introduction, Environment Variable, GET and POST Methods.

UNIT IV. PERL: Introduction, Variable, Condition, Loop, Array, Implementing data structure, Hash, String, Regular Expression, File handling, I/O handling. JavaScript: Basics, Statements, comments, variable, comparison, condition, switch, loop, break. Object - string, array, Boolean, reg-ex. Function, Errors, Validation. Cookies: Definition of cookies, Create and Store a cookie with example. Java Applets: Container Class, Components, Applet Life Cycle, Update method; Parameter passing applet, Applications.

UNIT V. Client-Server programming In Java: Java Socket, Java RMI. Threats: Malicious code-viruses, Trojan horses, worms; eavesdropping, spoofing, modification, denial of service attacks. Network security techniques: Password and Authentication; VPN, IP Security, security in electronic transaction, Secure Socket Layer (SSL), Secure Shell (SSH). Firewall: Introduction, Packet filtering, Stateful, Application layer, Proxy.

UNIT VI. Internet Telephony: Introduction, VoIP. Multimedia Applications: Multimedia over IP: RSVP, RTP, RTCP and RTSP. Streaming media, Codec and Plugins, IPTV. Search Engine and Web Crawler: Definition, Meta data, Web Crawler, Indexing, Page rank, overview of SEO.

REFERENCE BOOKS

- Web Technology: A Developer's Perspective, N.P. Gopalan and J. Akilandeswari, PHI, Learning, Delhi, 2013.
- Internetworking Technologies, An Engineering Perspective, Rahul Banerjee, PHI Learning, Delhi, 2011.

ARTIFICIAL INTELLIGENCE

1. Explain what constitutes "Artificial" Intelligence and how to identify systems with Artificial Intelligence.
2. Identify problems that are amenable to solution by AI methods, and which AI methods may be suited to solving a given problem.
3. Formalise a given problem in the language/framework of different AI methods (e.g., as a search problem, as a constraint satisfaction problem, as a planning problem, etc).
4. Implement basic AI algorithms (e.g., standard search or constraint propagation algorithms).
5. Design and perform an empirical evaluation of different algorithms on a problem formalisation, and state the conclusions that the evaluation supports.
6. Explain the limitations of current Artificial Intelligence techniques.

SYLLABUS

A. Theory **4 credits**

UNIT I. Introduction to Artificial Intelligence: Definition of AI; Turing Test; Brief History of AI. Problem Solving and Search: Problem Formulation; Search Space; States vs. Nodes; Tree Search: Breadth-First, Uniform Cost, Depth-First, Depth-Limited, Iterative Deepening; Graph Search.

UNIT II. Informed Search: Greedy Search; A* Search; Heuristic Function; Admissibility and Consistency; Deriving Heuristics via Problem Relaxation. Local Search: Hill-Climbing; Simulated Annealing; Genetic Algorithms; Local Search in Continuous Spaces.

UNIT III. Playing Games: Game Tree; Utility Function; Optimal Strategies; Minimax Algorithm; Alpha-Beta Pruning; Games with an Element of Chance. Beyond Classical Search: Searching with Nondeterministic Actions; Searching with Partial Observations; Online Search Agents; Dealing with Unknown Environments.

UNIT IV. Knowledge Representation and Reasoning: Ontologies, Foundations of Knowledge Representation and Reasoning, Representing and Reasoning about Objects, Relations, Events, Actions, Time, and Space; Predicate Logic, Situation Calculus, Description Logics, Reasoning with Defaults, Reasoning about Knowledge, Sample Applications.

UNIT V. Representing and Reasoning with Uncertain Knowledge: Probability, Connection to Logic, Independence, Bayes Rule, Bayesian Networks, Probabilistic Inference, and Sample Applications.

UNIT VI. Planning: The STRIPS Language; Forward Planning; Backward Planning; Planning Heuristics; Partial-Order Planning; Planning using Propositional Logic; Planning vs. Scheduling.

UNIT VII. Constraint Satisfaction Problems (CSPs): Basic Definitions; Finite vs. Infinite vs. Continuous Domains; Constraint Graphs; Relationship With Propositional Satisfiability, Conjunctive Queries, Linear Integer Programming, and Diophantine Equations; NP-

Completeness of CSP; Extension to Quantified Constraint Satisfaction (QCSP). Constraint Satisfaction as a Search Problem; Backtracking Search; Variable and Value Ordering Heuristic; Degree Heuristic; Least-Constraining Value Heuristic; Forward Checking; Constraint Propagation; Dependency-Directed Backtracking;

TEXT BOOKS

- Elaine Rich, Kevin Knight, Shivashankar B Nair, Artificial Intelligence, Third Edition, McGraw Hill Edition.

REFERENCE BOOKS

- Russell Stuart Jonathan and Norvig Peter, Artificial Intelligence: A Modern Approach, 3rd Edition, Prentice Hall, 2010

B. Practicum **2 credits**

The students are expected to explore the foundational skills on AI techniques acquired in theory in solving problems and using sample data sets and various tools prepare themselves for careers in AI industry. The following is an indicative list of assignme nts for the semester. However students should be encouraged to take-up mini-project using the techniques and tools explored in the lab to understand the true potential

1. Using simple Hill-climbing compute an approximate solution to the travelling salesperson problem.

2. Using Naïve bayes method learn a text classifier using training data and using test set evaluate the quality of the classifier.

3. Implement gradient descent and backpropagation in Python.

4. Using Scikit learn for Logistic regression, Support Vector Machines, Building Neural Networks.

5. Using inbuilt TensorFlow functionality to build a Neural Network and train on MNIST Dataset for classification.

6. Installation of Prolog and practicing queries using Prolog.

COMPUTER GRAPHICS

1. Acquire familiarity with the concepts and relevant mathematics of computer graphics.
2. Ability to implement various algorithms to scan, convert the basic geometrical primitives, transformations, area filling, clipping.
3. Describe the importance of viewing and projections.
4. Ability to design basic graphics application programs.
5. Familiarize with fundamentals of animation and Virtual reality technologies
6. Be able to design applications that display graphic images to given specifications.
7. To understand a typical graphics pipeline.

SYLLABUS

A. Theory **4 credits**

UNIT I. Application Areas of Computer Graphics, Overview of Graphics Systems and Devices. Points and Lines, Line Drawing Algorithms, Mid-Point Circle and Ellipse Algorithms. Filled Area Primitives, Polygon Filling Algorithms. Curve Generation: Bezier and B-Spline Curves.

UNIT II. 2-D Geometrical Transforms: Translation, Scaling, Rotation, Reflection and Shear Transformations Composite Transforms, Transformations between Coordinate Systems. 2-D Viewing: The Viewing Pipeline, Viewing Coordinate Reference Frame, Window to Viewport Coordinate Transformation, Viewing Functions.

UNIT III. Line Clipping Algorithms- Cohen-Sutherland and Cyrus Beck Line Clipping Algorithms, Sutherland–Hodgeman Polygon Clipping Algorithm. 3-D Object Representation: Polygon Surfaces, Quadric Surfaces, Spline Representation

UNIT IV. 3-D Geometric Transformations: Translation, Rotation, Scaling, Reflection and Shear Transformations, Composite Transformations, 3-D Viewing: Viewing Pipeline, Viewing Coordinates, View Volume, General Projection Transforms and Clipping.

UNIT V. Visible Surface Detection Methods: Classification, Back-Face Detection, Depth-Buffer, Scanline, Depth Sorting, BSP-Tree Methods, Area Sub-Division and Octree Methods Illumination Models and Surface Rendering Methods: Basic Illumination Models, Polygon Rendering Methods Computer Animation: Design of Animation Sequence, General Computer Animation Functions Key Frame Animation, Animation Sequence, Motion Control Methods, Morphing, Warping (Only Mesh Warping)

UNIT VI. Virtual Reality : Basic Concepts, Classical Components of VR System, Types of VR Systems, Three Dimensional Position Trackers, Navigation and Manipulation Interfaces, Gesture Interfaces. Input Devices, Graphical Rendering Pipeline, Haptic Rendering Pipeline, Open GL Rendering Pipeline. Applications of Virtual Reality.

TEXTBOOKS

- Donald Hearn and M. Pauline Baker, “Computer Graphics with Open GL”, Prentice Hall.
- R. K Maurya, “Computer Graphics with Virtual Reality”, Wiley

REFERENCE BOOKS

- “Computer Graphics Principles & practice”, Foley, Van Dam, Feiner and Hughes, Pearson Education.

B. Practicum **2 credits**

The students are required to create interactive graphics applications in C using graphics application programming interfaces and demonstrate geometrical transformations. The lab material includes implementation of line drawings, circle drawing, ellipse drawing as well as different geometrical transformations.

Experiment 1: Line Drawing Using DDA and Bresenham
Experiment 2: Circle Drawing Using Midpoint Algorithm .
Experiment 3: Ellipse Drawing Using Mipoint Algorithm.
Experiment 4: Performing the basic 2D transformations such as translation, Scaling, Rotation, shearing and reflection for a given 2D object.

MACHINE LEARNING

1. Differentiate between supervised, unsupervised machine learning approaches
2. Ability to choose appropriate machine learning algorithm for solving a problem
3. Design and adapt existing machine learning algorithms to suit applications
4. Understand the underlying mathematical relationships across various machine learning algorithms
5. Design and implement machine learning algorithms to real world applications

SYLLABUS **6 credits**

UNIT I. Introduction: Concept of Machine Learning, Applications of Machine Learning, Key elements of Machine Learning, Supervised vs. Unsupervised Learning, Statistical Learning: Bayesian Method, The Naive Bayes Classifier

UNIT II. Software's for Machine Learning and Linear Algebra Overview: Plotting of Data, Vectorization, Matrices and Vectors: Addition, Multiplication, Transpose and Inverse using Available Tool such as MATLAB.

UNIT III. Linear Regression: Prediction using Linear Regression, Gradient Descent, Linear Regression with one Variable, Linear Regression with Multiple Variables, Polynomial Regression, Feature Scaling/Selection.

UNIT IV. Logistic Regression: Classification using Logistic Regression, Logistic Regression vs. Linear Regression, Logistic Regression with one Variable and with Multiple Variables.

UNIT V. Regularization: Regularization and its Utility: The problem of Overfitting, Application of Regularization in Linear and Logistic Regression, Regularization and Bias/Variance.

UNIT VI. Neural Networks: Introduction, Model Representation, Gradient Descent vs. Perceptron Training, Stochastic Gradient Descent, Multilayer Perceptrons, Multiclass Representation, Back Propagation Algorithm.

TEXT BOOKS

- Ethem Alpaydin, "Introduction to Machine Learning" 2nd Edition, The MIT Press, 2009.
- Tom M. Mitchell, "Machine Learning", First Edition by Tata McGraw-Hill Education, 2013.
- Christopher M. Bishop, "Pattern Recognition and Machine Learning" by Springer, 2007.
- Mevin P. Murphy, "Machine Learning: A Probabilistic Perspective" by The MIT Press, 2012.

IMAGE PROCESSING

1. To familiarize the students with the image fundamentals and mathematical transforms necessary for image processing.
2. To make the students understand the image enhancement techniques
3. To make the students understand the image restoration and reconstruction procedures.
4. To familiarize the students with the image segmentation procedures.

SYLLABUS **6 credits**

UNIT I Digital Image Fundamentals: Elements of Visual Perception, Light, Brightness Adaption and Discrimination, Image Sensing and Acquisition, Image Sampling and Quantization, Pixels, Some Basic Relationships between Pixels, Coordinate Conventions, Imaging Geometry, Perspective Projection, Linear and Nonlinear Operations

UNIT II Image Enhancement in the Spatial Domain: Intensity transformations, Contrast Stretching, Histogram Equalization, Correlation and Convolution, Basics of Spatial Filtering, Smoothing Filters, Sharpening Filters, Gradient and Laplacian.

UNIT III Filtering in the Frequency domain: Hotelling Transform, Fourier Transforms and properties, FFT (Decimation in Frequency and Decimation in Time Techniques), Convolution, Correlation, 2-D sampling, Discrete Cosine Transform, Frequency domain filtering.

UNIT IV Image Restoration and Reconstruction: Basic Framework, Interactive Restoration, Image deformation and geometric transformations, image morphing, Restoration techniques, Noise characterization, Noise restoration filters, Adaptive filters, Linear, Position invariant degradations, Estimation of Degradation functions, Restoration from projections.

UNIT V Color Image Processing, Color Fundamentals, Color Models, Pseudocolor Image Processing, Basics of Full-Color Image Processing, Color Transformations, Smoothing and Sharpening, Color Segmentation. Morphological Image Processing, Dilation and Erosion, Opening and Closing., Extensions to Gray -Scale Images.

UNIT VI Image Segmentation: Detection of Discontinuities, Edge Linking and Boundary Detection, Thresholding, Region-Based Segmentation, Segmentation by Morphological Watersheds.

TEXT BOOKS

- Digital Image Processing, Rafael C. Gonzalez and Richard E. Woods, 4th Edition, Prentice Hall.

REFERENCE BOOKS

- Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall.
- Stan Birchfield, Image Processing and Analysis, Cengage Learning.

DATA ANALYTICS

1. This course prepares students to gather, describe, and analyze data, and use advanced statistical tools to support decision making.
2. To gather sufficient relevant data, conduct data analytics using scientific methods, and understand appropriate connections between quantitative analysis and real-world problems.
3. Understand the exact scopes and possible limitations of each method to provide constructive guidance in decision making.
4. To Use advanced techniques to conduct thorough and insightful analysis, and interpret the results correctly with detailed and useful information.
5. To make better decisions by using advanced techniques in data analytics.

SYLLABUS **6 credits**

UNIT I. Data Definitions and Analysis Techniques: Elements, Variables, and Data Categorization, Levels of Measurement, Data Management and Indexing

UNIT II. Descriptive Statistics: Measures of Central Tendency, Measures of Location of Dispersions, Error Estimation and Presentation (Standard Deviation, Variance), Introduction to Probability

UNIT III. Basic Analysis Techniques: Statistical Hypothesis Generation and Testing, Chi-Square Test, T-Test, Analysis of Variance, Correlation Analysis, Maximum Likelihood Test

UNIT IV. Data Analysis Techniques-I: Regression Analysis, Classification Techniques, Clustering Techniques (K-Means, K-Nearest Neighborhood) UNIT

V. Data Analysis Techniques-II: Association Rules Analysis, Decision Tree

UNIT VI. Introduction to R Programming: Introduction to R Software Tool, Statistical Computations using R (Mean, Standard Deviation, Variance, Regression, Correlation etc.)

UNIT VII. Practice and Analysis with R and Python Programming, Sensitivity Analysis

REFERENCE BOOKS

- Probability and statistics for Engineers and Scientists (9 Edn.), Ronald E Walppole, Raymond H Myres, Sharon L. Myres and Leying Ye, Prentice Hall Inc
- The Elements of Statistical Learning, Data Mining, Inference, and Prediction (2nd Edn.) Travor Hastie Robert Tibshirani Jerome Friedman, Springer, 2014

- Software for Data Analysis: Programming with R (Statistics and Computing), John M. Chambers, Springer

COMPUTER ETHICS

1. The student will be able to describe and distinguish between the various ethical theories which can be used to form the basis of solutions to moral dilemmas in computing.
2. Identify traditional and current Issues related to Computers, Information Systems, Ethics, Society and Human Values;
3. The student will be able to identify and define the components of a structured plan for solving ethical problems and, in the process, will be able to understand the basis for her/his own ethical system.
4. Given several examples of professional codes of ethics related to computing, the student will be able to compare and contrast these examples, discussing their commonalties, differences, and implications.
5. Develop skills of critical analysis and applying ethical principles to situations and dialectical thinking

SYLLABUS **6 credits**

UNIT I. The Need for Computer Ethics Training and Historical Milestones

UNIT II. Defining the Field of Computer Ethics, Computer ethics codes, Sample Topics in Computer Ethics

i. Computer crime and computer security
ii. Software theft and intellectual property rights
iii. Computer hacking and the creation of viruses
iv. Computer and information system failure
v. Invasion of privacy. Privacy in the Workplace and on the Internet
vi. Social implications of artificial intelligence and expert systems
vii. The information technology salesman issues

UNIT III. Transparency and Virtual Ethics, Free Speech, Democracy, Information Access

UNIT IV. Developing the Ethical Analysis Skills and Professional Values, Privacy, Accountability, Government Surveillance

UNIT V. Boundaries of Trust, Trust Management, Wikipedia, Virtual Trust, Plagiarism in Online Environment, Intellectual Property, Net neutrality

REFERENCE BOOKS

- Deborah, J, Nissenbaun, H, Computing, Ethics & Social Values, Englewwod Cliffs, New Jersey, Prentice Hall, 1995.
- Spinello, R, Tavani, H, T, Readings in Cyberethics, Sudbury, MA, Jones and Bartlett Publishers, 2001.
- Bynum, T, W; Rogerson, S, Computer Ethics and Professional Responsibility, Blackwell, 2004

SYSTEM SECURITY

1. Develop an understanding of information assurance as practiced in computer operating systems, distributed systems, networks and representative applications.
2. Gain familiarity with prevalent network and distributed system attacks, defenses against them, and forensics to investigate the aftermath.
3. Develop a basic understanding of cryptography, how it has evolved, and some key encryption techniques used today.
4. Develop an understanding of security policies (such as authentication, integrity and confidentiality), as well as protocols to implement such policies in the form of message exchanges.

SYLLABUS **6 Credits**

UNIT 1. Cryptographic Tools- Confidentiality with Symmetric Encryption, Message Authentication and Hash Functions, Public-Key Encryption, Digital Signatures and Key Management, Random and Pseudorandom Numbers, Practical Application: Encryption of Stored Data

UNIT 2. User Authentication- Means of Authentication, Password-Based Authentication, Token-Based Authentication, Biometric Authentication, Remote User Authentication, Security Issues for User Authentication, Practical Application: An Iris Biometric System, Case Study: Security Problems for ATM Systems

UNIT 3. Access Control- Access Control Principles, Subjects, Objects, and Access Rights, Discretionary Access Control, Example: UNIX File Access Control, Role-Based Access Control, Case Study: RBAC System for a Bank

UNIT 4. Database Security-The Need for Database Security, Database Management Systems, Relational Databases, Database Access Control, Inference, Statistical Databases, Database Encryption, Cloud Security

UNIT 5. Malicious Software-Types of Malicious Software (Malware), Propagation–Infected Content–Viruses, Propagation–Vulnerability Exploit–Worms, Propagation–Social Engineering–SPAM E-mail, Trojans, Payload–System Corruption, Payload–Attack Agent–Zombie, Bots, Payload–Information Theft–Keyloggers, Phishing, Spyware, Payload–Stealthing–Backdoors, Rootkits,, Countermeasures

UNIT 6. Denial-of-Service Attacks- Denial-of-Service Attacks, Flooding Attacks, Distributed Denial-of-Service Attacks, Application-Based Bandwidth Attacks, Reflector and Amplifier Attacks, Defenses Against Denial-of-Service Attacks, Responding to a Denial-of-Service Attack.

TEXT BOOKS

- M. Stamp, “Information Security: Principles and Practice,” 2 st Edition, Wiley, ISBN: 0470626399, 2011.
- M. E. Whitman and H. J. Mattord, “Principles of Information Security,” 4 st Edition, Course Technology, ISBN: 1111138214, 2011.
- M. Bishop, “Computer Security: Art and Science,” Addison Wesley, ISBN: 0-201-44099-7, 2002.
- G. McGraw, “Software Security: Building Security In,” Addison Wesley, ISBN: 0321356705, 2006.

HUMAN COMPUTER INTERFACE

1. Provide an overview of the concepts relating to the design of human-computer interfaces in ways making computer-based systems comprehensive, friendly and usable.
2. Understand the theoretical dimensions of human factors involved in the acceptance of computer interfaces.
3. Understand the important aspects of implementation of human-computer interfaces.
4. Identify the various tools and techniques for interface analysis, design, and evaluation.
5. Identify the impact of usable interfaces in the acceptance and performance utilization of information systems.

SYLLABUS **6 credits**

UNIT I. Introduction: Historical Evolution of HCI, Interactive System Design: Concept of Usability- Definition and Elaboration, HCI and Software Engineering, GUI Design and Aesthetics, Prototyping Techniques

UNIT II. Model-Based Design and Evaluation: Basic Idea, Introduction to Different Types of Models, GOMS Family of Models (KLM And CMN-GOMS), Fitts' Law and Hickhyman's Law,

UNIT III. General Development Guidelines and Principles: Shneiderman's Eight Golden Rules, Norman's Seven Principles, Norman's Model of Interaction, Nielsen's Ten Heuristics with Example of its use, Contextual Inquiry

UNIT IV. Dialog Design: Introduction to Formalism in Dialog Design, Design using FSM (Finite State Machines), State Charts and (Classical) Petri Nets in Dialog Design

UNIT V. Task Modeling and Analysis: Hierarchical Task Analysis (HTA), Engineering Task Models and Concur Task Tree (CTT)

UNIT VI. Object Oriented Modelling: Object Oriented Principles, Definition of Class and Object and their Interactions, Object Oriented Modelling for User Interface Design, Case Study Related to Mobile Application Development

REFERENCE BOOKS

- Dix A., Finlay J.,Abowd G. D. and Beale R. Human Computer Interaction, 3 rd edition, Pearson Education, 2005.
- Preece J., Rogers Y.,Sharp H.,Baniyon D., Holland S. and Carey T. Human Computer Interaction,Addison-Wesley, 1994.
- B.Shneiderman; Designing the User Interface,Addison Wesley 2000 (Indian Reprint).

MODELLING AND SIMULATIONS

1. Characterise systems in terms of their essential elements, purpose, parameters, constraints, performance requirements, sub-systems, interconnections and environmental context.
2. Understand the technical underpinning of modern computer simulation software.
3. System problem modelling and solving through the relationship between theoretical, mathematical, and computational modelling for predicting and optimizing performance and objective.
4. Mathematical modelling real world situations related to information systems development, prediction and evaluation of outcomes against design criteria.
5. Develop solutions and extract results from the information generated in the context of the information systems
6. Interpret the model and apply the results to resolve critical issues in a real world environment.
7. Develop different models to suit special characteristics of the system being modelled.

SYLLABUS **6 credits**

UNIT 1. **Systems and environment:** Concept of model and model building, model classification and representation, Use of simulation as a tool, steps in simulation study.

UNIT 2. **Continuous-time and Discrete-time systems:** Laplace transform, transfer functions, statespace models, order of systems, z-transform, feedback systems, stability, observability, controllability. Statistical Models in Simulation: Common discrete and continuous distributions, Poisson process, empirical distributions

UNIT 3. **Random Numbers:** Properties of random numbers, generation of pseudo random numbers, techniques of random number generation, tests for randomness, random variate generation using inverse transformation, direct transformation, convolution method, acceptance-rejection

UNIT 4. **Design and Analysis of simulation experiments:** Data collection, identifying distributions with data, parameter estimation, goodness of fit tests, selecting input models without data, multivariate an time series input models, verification and validation of models, static and dynamic simulation output analysis, steady-state simulation, terminating simulation, confidence interval estimation, Output analysis for steady state simulation, variance reduction techniques

UNIT 5. **Queuing Models:** Characteristics of queuing systems, notation, transient and steady state behavior, performance, network of queues

UNIT 6. **Large Scale systems:** Model reduction, hierarchical control, decentralized control, structural properties of large-scale systems

REFERENCE BOOKS

- Shailendra Jain, Modeling and Simulation using MATLAB - Simulink, 2ed, Kindle edition

THEORY OF COMPUTATION

1. To provide a formal connection between algorithmic problem solving and the theory of languages and automata and develop them into a mathematical (abstract) view towards algorithmic design and in general computation itself.

2. The course should in addition clarify the practical view towards the applications of these ideas in the engineering part as well.

3. Become proficient in key topics of theory of computation, and to have the opportunity to explore the current topics in this area

PREREQUISITE

Students should have a background in discrete mathematics, data structures, and programming languages.

SYLLABUS

A THEORY **4 Credits**

UNIT I. Automata: Introduction to Formal Proof, Additional Forms of Proof, Inductive Proofs, Finite Automata (FA), Deterministic Finite Automata (DFA), Non-Deterministic Finite Automata (NFA), Finite Automata with Epsilon Transitions

UNIT II. Regular Expressions and Languages: Regular Expression, FA and Regular Expressions, Proving Languages not to be Regular, Closure Properties of Regular Languages, Equivalence and Minimization of Automata

UNIT III. Context Free Grammars and Languages: Context Free Grammar (CFG), Parse Trees , Ambiguity in Grammars and Languages, Definition of The Pushdown Automata, Languages of a Pushdown Automata, Equivalence of Pushdown Automata and CFG Deterministic Pushdown Automata.

UNIT IV. Properties of Context Free Languages: Normal Forms for CFG, Pumping Lemma for CFL, Closure Properties of CFL, Turing Machines, Programming Techniques for TM, Variations of TM, Non Universal TM, Universal TM.

UNIT V. Undecidability: A Language that is not Recursively Enumerable (RE), an Undecidable Problem that is RE, Undecidable Problems about Turing Machine, Post's Correspondence Problem, The Classes P and NP.

REFERENCE BOOKS

- J.E. Hopcroft, R. Motwani and J.D. Ullman, "Introduction to Automata Theory, Languages and Computations", second Edition, Pearson Education, 2007.
- H.R. Lewis and C.H. Papadimitriou, "Elements of the theory of Computation", Second Edition, Pearson Education, 2003.

- Thomas A. Sudkamp," An Introduction to the Theory of Computer Science, Languages and Machines", Third Edition, Pearson Education., 2007.
- J. Martin, "Introduction to Languages and the Theory of computation, Third Edition, Tata Mc Graw Hill, 2007.

B. Practicum **2 credits**

The students are expected to understand the Hierarchy of formal languages with reference to their varying degrees of complexity in recognising them. Programs can be designed after designing suitable automata to recognize the following formal languages. Given an input the recognizer shall output a Yes/No answer depending on whether the string is part of the language or not.

1. Language of Binary strings which ends with the pattern 101.
2. Language of Binary strings such that the third symbol from the end is a Zero
3. Language of parenthesised expressions with matching left and right parenthesis
4. Language of Binary strings with equal number of Zeros and Ones
5. Language generated by the grammar $\{a^n b^n c^n \mid n^3\ 1\}$
6. Language $\{ a^p \mid p \text{ is prime}\}$

DATA MINING

1. Demonstrate advanced knowledge of data mining concepts and techniques.
2. Apply the techniques of clustering, classification, association finding, feature selection and visualisation on real world data
3. Determine whether a real world problem has a data mining solution
4. Apply data mining software and toolkits in a range of applications
5. Set up a data mining process for an application, including data preparation, modelling and evaluation
6. Demonstrate knowledge of the ethical considerations involved in data mining.

SYLLABUS **6 credits**

UNIT I. Introduction to Data Mining, Understanding Data, Relations to Database, Statistics, Machine Learning

UNIT II. Association Rule Mining, Level-wise Method, FP-Tree Method, Other Variants

UNIT III. Classification, Decision Tree Algorithm, CART, PUBLIC, Pruning Classification Tree

UNIT IV. Clustering Techniques, Clustering of Numeric Data, of Ordinal Data, Efficiency of Clustering, Consensus Clustering, Spectral Clustering

UNIT V. Rough Set Theory and its Application to Data Mining

UNIT VI. ROC Analysis

UNIT VII. Data Mining Trends, Big Data, Data Analytics

TEXT BOOKS

- Data Mining Techniques (4e) Universities Press Arun K Pujari

CLOUD COMPUTING

1. Analyze the trade-offs between deploying applications in the cloud and over the local infrastructure.
2. Compare the advantages and disadvantages of various cloud computing platforms.
3. Deploy applications over commercial cloud computing infrastructures such as Amazon Web Services, Windows Azure, and Google AppEngine.
4. Program data intensive parallel applications in the cloud.
5. Analyze the performance, scalability, and availability of the underlying cloud technologies and software.
6. Identify security and privacy issues in cloud computing.
7. Explain recent research results in cloud computing and identify their pros and cons.
8. Solve a real-world problem using cloud computing through group collaboration.

SYLLABUS

A. **Theory** **4 Credits**

Unit I. Introduction to cloud computing
Definition, characteristics, components, Cloud service provider, the role of networks in Cloud computing, Cloud deployment models- private, public & hybrid, Cloud service models, multitenancy, Cloud economics and benefits, Cloud computing platforms - IaaS: Amazon EC2, PaaS: Google App Engine, Microsoft Azure, SaaS.

Unit II. Virtualization
Virtualization concepts , Server virtualization, Storage virtualization, Storage services, Network virtualization, Service virtualization, Virtualization management, Virtualization technologies and architectures, virtual machine, Measurement and profiling of virtualized applications. Hypervisors: KVM, Xen, VMware hypervisors and their features.

Unit III. Data in cloud computing
Relational databases, Cloud file systems: GFS and HDFS, BigTable, HBase and Dynamo. MapReduce and extensions: Parallel computing, the map-Reduce model, Parallel efficiency of MapReduce, Relational operations using Map-Reduce, Enterprise batch processing using MapReduce.

Unit IV. Cloud security
Cloud security fundamentals, Vulnerability assessment tool for cloud, Privacy and Security in cloud. Cloud computing security architecture: General Issues, Trusted Cloud computing, Secure Execution Environments and Communications, Micro - architectures; Identity Management and Access control, Autonomic security, Security challenges : Virtualization security management - virtual threats, VM Security Recommendations, VM - Specific Security techniques, Secure Execution Environments and Communications in cloud.
Unit V. Issues in cloud computing
Implementing real time application over cloud platform, Issues in Inter-cloud environments, QOS Issues in Cloud, Dependability, data migration, streaming in Cloud. Quality of Service (QoS) monitoring in a Cloud computing environment. Cloud Middleware. Mobile Cloud Computing. Inter Cloud issues. A grid of clouds, Sky computing, load balancing, resource optimization, resource dynamic reconfiguration, Monitoring in Cloud

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TEXT BOOK:

1. Enterprise Cloud Computing by Gautam Shroff,Cambridge publication

REFERENCE BOOK:

1. Cloud Security by Ronald Krutz and Russell Dean Vines, Wiley-India
2.. Dr. Kumar Saurabh,"Cloud Computing", Wiley Publication

B. **Practicum** **2 Credits**

The students shall explore development of web applications in cloud. Practically Design and develop processes involved in creating a cloud based application and programming using Hadoop

Indicative List of Experiments

1. Install Virtualbox/VMware Workstation with different flavours of linux or windows OS with virtualization support
2. Install a C compiler in the virtual machine created using virtual box and execute Simple Programs
3. Install Google App Engine. Create hello world app and other simple web applications using python/java.
4. Simulate a cloud scenario using CloudSim and run a scheduling algorithm that is not present in CloudSim.
5. Experiment a procedure to transfer the files from one virtual machine to another virtual machine.
6. Experiment a procedure to launch virtual machine using trystack (Online Openstack Demo Version)
7. Install Hadoop single node cluster and run simple applications like word count.

INTERNET OF THINGS

1. To learn the concepts of Sensors, Wireless Network and Internet
2. To learn and implement use of Devices in IoT technology.
3. To learn the different IoT Technologies like Micro-controller, Wireless communication like Blue Tooth, GPRS, Wi-Fi and Storage and embedded systems
4. To understand how to program on embedded and mobile platforms including different Microcontrollers like ESP8266, Raspberry Pi, Arduino and Android programming
5. To understand how to make sensor data available on the Internet (data acquisition) and understand how to analyze and visualize sensor data
6. To understand, analysis and evaluate different protocols used in IoT.
7. To learn basic python programming for IoT applications
8. To learn and design different applications in IoT.
9. To design, develop and test different prototypes in IoT.

SYLLABUS **6 credits**

UNIT I. (Introduction to IoT, Sensors and Actuators) Introduction to IoT: Definition, Characteristics, Applications, Evolution, Enablers, Connectivity Layers, Addressing, Networking and Connectivity Issues, Network Configurations, Multi-Homing, Sensing: Sensors and Transducers, Classification, Different Types of Sensors, Errors, Actuation: Basics, Actuator Types- Electrical, Mechanical Soft Actuators

UNIT II. (Introduction to Networking, Communication Protocols and Machine-to-Machine Communication) Basics of Networking, Communication Protocols, Sensor Network, Machine to Machine Communication (IoT Components, Inter-Dependencies, SoA, Gateways, Comparison Between IoT & Web, Difference Protocols, Complexity of Networks, Wireless Networks, Scalability, Protocol Classification, MQTT & SMQTT, IEEE 802.15.4, Zigbee)

UNIT III. (Arduino Programming) Interoperability in IoT, Introduction To Arduino Programming, Integration Of Sensors And Actuators With Arduino

UNIT IV. (Python Programming and Raspberry Pi) Introduction to Python Programming, Introduction to Raspberry Pi, Implementation of IoT with Raspberry Pi, Implementation of IoT with Raspberry Pi

UNIT V. (Data Analytics and Cloud Computing) Data Handling and Analytics, Cloud Computing Fundamentals, Cloud Computing Service Model, Cloud Computing Service Management and Security, Sensor-Cloud Architecture, View and Dataflow

UNIT VI. (FOG Computing and Case Studies) FOG Computing: Introduction, Architecture, Need, Applications and Challenges

UNIT VII. Industrial IoT, Case Studies: Agriculture, Healthcare, Activity Monitoring

REFERENCE BOOKS

- The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj and Anupama C. Raman (CRC Press).
- Internet of Things: A Hands-on Approach", by A Bahga and Vijay Madisetti (Universities Press)

MATLAB PROGRAMMING

1. Understand the fundaments of procedural and functional programming;
2. Understand Matlab data types and structures;
3. Be able to set up simple real-life numerical problems such that they can be solved and visualized using basic codes in Matlab;
4. Be ready to use advanced coding in Matlab in their subsequent studies

SYLLABUS **4 Credits**

UNIT 1. Introduction to MATLAB Programming- Basics of MATLAB programming, Array operations in MATLAB, Loops and execution control, Working with files: Scripts and Functions, Plotting and program output

UNIT 2. Approximations and Errors- Defining errors and precision in numerical methods, Truncation and round-off errors, Error propagation, Global and local truncation errors

UNIT 3. Linear Equations- Linear algebra in MATLAB, Gauss Elimination, LU decomposition and partial pivoting, Iterative methods: Gauss Siedel Method

UNIT 4. Regression and Interpolation- Introduction, Linear least squares regression(including lsqcurvefit function), Functional and nonlinear regression (including *lsqnonlin* function), Interpolation in MATLAB using spline and *pchip*

UNIT 5. Nonlinear Equations- Nonlinear equations in single variable, MATLAB function fzero in single variable, Fixed-point iteration in single variable, Newton-Raphson in single variable, MATLAB function *fsolve* in single and multiple variables, Newton-Raphson in multiple variables

TEXT BOOKS

1. Fausett L.V.(2007) Applied NumericalAnalysis Using MATLAB, 2nd Ed.,Pearson Education
2. Essential MATLAB for Engineers and Scientists, 6th Edition, Brian Hahn; Daniel T. Valentine, Academic Press, Web ISBN-13: 978-0-12-805271-6,

PROGRAMMING IN JAVA

1. Knowledge of the structure and model of the Java programming language,
2. Use the Java programming language for various programming technologies
3. Develop software in the Java programming language,
4. Evaluate user requirements for software functionality required to decide whether the Java programming language can meet user requirements

SYLLABUS **4 credits**

A. Theory

UNIT I. Introduction: Java Essentials, Its characteristics, Execution and Compilation, Data types, Variables, Control Statements, Standard Input/ Output.

UNIT II. Constructors, Object Oriented Concepts: Encaptulation, Abstraction, Inheritance, Polymorphisms, JAVA Packages.

UNIT III. Exception Handling, Wrapper Classes, Autoboxing, Multi-thread Programming.

UNIT IV. Applets, Event Handling, AWT, Database Handling using JDBC.

TEXT BOOKS

- E Balaguruswamy, Programming with JAVA, A Primer (5e), Kindle Edition

REFERENCE BOOKS

- Bruce Eckel, Thinking in Java (4e)
- Herbert Schildt, Java: The Complete Reference (9e)
- Y. Daniel Liang, Introduction to Java Programming (10e)
- Paul Deitel, Harvey Deitel, Java: How To Program (10e)
- Cay S. Horsttnann, Core Java Volume I –Fundamentals (10e)

B. Practicum

Students are required to implement object-oriented paradigm using JAVA. Below are the list of some of the experiments.

Part A

1. Program on strings: Check the equality of two strings, Reverse a string.
2. Program using loops: to find the sum of digits of a given number, display a multiplication table, display all prime numbers between 1 to 1000.
3. Program to demonstrate all math class functions.

Part B

4. Program on files : to copy a file to another file using Java to package classes.
5. Program to demonstrate method over-riding and overloading
6. Programs on inheritances.
7. Multi-threaded programming.

PYTHON PROGRAMMING

1. Develop and Execute simple Python programs.
2. Structure a Python program into functions.
3. Using Python lists, tuples to represent compound data
4. Develop Python Programs for file processing

SYLLABUS

A Theory **4 Credits**

UNIT I. Introduction to Python, Python, Features of Python, Execution of a Python, Program, Writing Our First Python Program, Data types in Python. Python Interpreter and Interactive Mode; Values and Types: int, float, boolean, string, and list; Variables, Expressions, Statements, Tuple Assignment, Precedence of Operators, Comments; Modules and Functions, Function Definition and use, Flow of Execution, Parameters and Arguments

UNIT II. Operators in Python, Input and Output, Control Statements. Boolean Values and operators, Conditional (if), Alternative (if-else), Chained Conditional (if-elif-else); Iteration: state, while, for, break, continue, pass; Fruitful Functions: Return Values, Parameters, Local and Global Scope, Function Composition, Recursion

UNIT III. Arrays in Python, Strings and Characters. Strings: String Slices, Immutability, String Functions and Methods, String Module; Lists as Arrays. Illustrative Programs: Square Root, gcd, Exponentiation, Sum an Array of Numbers, Linear Search, Binary Search.

UNIT IV. Functions, Lists and Tuples. List Operations, List Slices, List Methods, List Loop, Mutability, Aliasing, Cloning Lists, List Parameters; Tuples: Tuple Assignment, Tuple as Return Value; Dictionaries: Operations and Methods; Advanced List Processing - List Comprehension; Illustrative Programs: Selection Sort, Insertion Sort, Merge sort, Histogram.

UNIT V. Files and Exception: Text Files, Reading and Writing Files, Format Operator; Command Line Arguments, Errors and Exceptions, Handling Exceptions, Modules, Packages; Illustrative Programs: Word Count, Copy File.

TEXT BOOKS

- Mark Lutz, Learning Python
- Tony Gaddis, Starting Out With Python
- Kenneth A. Lambert, Fundamentals of Python
- James Payne, Beginning Python using Python 2.6 and Python 3

B. Practicum **2 Credits**

The students are required to verify their ablility to use core programming basics and program design with functions using Python programming language. The teacher shall programs to strengthen the practical expertise of the students. The following is an indicative list of programs that can be practised

1. Write a program to demonstrate different number data types in Python.

2. Write a program to perform different Arithmetic Operations on numbers in Python.

3. Write a program to create, concatenate and print a string and accessing sub-string from a given string.

4. Write a python script to print the current date in the following format "Fri Oct 11 02:26:23 IST 2019"

5. Write a program to create, append, and remove lists in python.

6. Write a program to demonstrate working with tuples in python.

7. Write a program to demonstrate working with dictionaries in python.

8. Write a python program to find largest of three numbers.

9. Write a Python program to construct the following pattern, using a nested for loop

```
*
* *
* * *
* * * *
* * * * *
* * * *
* * *
* *
*
```

10. Write a Python script that prints prime numbers less than 20.

11. Write a python program to define a module to find Fibonacci Numbers and import the module to another program.

12. Write a python program to define a module and import a specific function in that module to another program.

13. Write a program that inputs a text file. The program should print all of the unique words in the file in alphabetical order.

14. Write a Python class to convert an integer to a roman numeral.

15. Write a Python class to reverse a string word by word.

MOBILE APPLICATION DEVELOPMENT

1. To understand Android platform and its architecture.
2. To learn about mobile devices types and different modern mobile operating systems.
3. To learn activity creation and Android User Interface designing.
4. To learn basics of Intent, Broadcast and Internet services.
5. To learn about different wireless mobile data transmission standards.
6. To understand and learn how to integrate basic phone features, multimedia, camera and Location based services in Android Application.
7. To learn about different systems for mobile application development, deployment and distribution in Mobile market place (Android, IoS).
8. To understand and carry out functional test strategies for mobile applications.

SYLLABUS **4 credits**

UNIT I. (Introduction) What is Android, Android Versions and its Feature Set, Various Android Devices on the Market, Android Market Application Store, Android Development Environment System Requirements, Android SDK, Installing Java, and ADT bundle - Eclipse Integrated Development Environment (IDE), Creating Android Virtual Devices (AVDs)

UNIT II. (Android Architecture Overview and Application) Android Software Stack, The Linux Kernel, Android Runtime - Dalvik Virtual Machine, Android Runtime – Core Libraries, Dalvik VM Specific Libraries, Java Interoperability Libraries, Android Libraries, Application Framework, Creating a New Android Project ,Defining the Project Name and SDK Settings, Project Configuration Settings, Configuring the Launcher Icon, Creating an Activity, Running the Application in the AVD, Stopping a Running Application, Modifying the Example Application, Reviewing the Layout and Resource Files,

UNIT III. (Android Software Development Platform and Framework) Understanding Java SE and the Dalvik Virtual Machine, The Directory Structure of an Android Project, Common Default Resources Folders, The Values Folder, Leveraging Android XML, Screen Sizes , Launching Mobile Application: The AndroidManifest.xml File, Android Application Components, Android Activities: Defining the UI, Android Service s: Processing in the Background, Broadcast Receivers: Announcements and Notifications Content Providers: Data Management, Android Intent Objects: Messaging for Components, Android Manifest XML: Declaring Your Components

UNIT IV. (Understanding Android User Interfaces, Views and Layouts) Designing for Different Android Devices, Views and View Groups, Android Layout Managers, The View Hierarchy, Designing an Android User Interface using the Graphical Layout Tool Displaying Text with TextView, Retrieving Data from Users, Using Buttons, Check Boxes and Radio Groups, Getting Dates and Times from Users, Using Indicators to Display Data to Users, Adjusting Progress with Seek Bar, Working with Menus using views, Gallery, Image Switcher, Grid View, and Image View views to display images, Creating Animation

UNIT V. (Databases, Intents, Location-based Services) Saving and Loading Files, SQLite Databases, Android Database Design, Exposing Access to a Data Source through a Content

Provider, Content Provider Registration, Native Content Providers Intents and Intent Filters: Intent Overview, Implicit Intents, Creating the Implicit Intent Example Project, Explicit Intents, Creating the Explicit Intent Example Application, Intents with Activities, Intents with Broadcast Receivers

UNIT VI. Sending SMS Messages Programmatically, Getting Feedback after Sending the Message Sending SMS Messages Using Intent Receiving, sending email, Introduction to location-based service, configuring the Android Emulator for Location-Based Services, Geocoding and Map-Based Activities Multimedia: Audio, Video, Camera: Playing Audio and Video, Recording Audio and Video, Using the Camera to Take and Process Pictures

REFERENCE BOOKS

- Android Programming Unleashed (1^{st} Edition) by Harwani.
- Beginning Mobile Application Development in the Cloud (2011), Richard Rodger.

WEB PROGRAMMING

1. To understand basics of the Internet and World Wide Web
2. To acquire knowledge and skills for creation of web site considering both client and server-side programming
3. To learn basic skill to develop responsive web applications
4. To understand different web extensions and web services standards
5. To understand basic concepts of Search Engine Basics.
6. To learn Web Service Essentials.
7. To learn Rich Internet Application Technologies.
8. To understand and get acquainted with Web Analytics 2.0

SYLLABUS **4 credits**

UNIT I. (Introduction to World Wide Web) -Internet Standards, Introduction to WWW and WWW Architecture, Internet Protocols, Overview of HTTP, HTTP request – response, Generations of dynamic web pages

UNIT II. (User Interface Design) Introduction to HTML and HTML5, TML Tags, Formatting and Fonts, Commenting Code, Anchors, Backgrounds, Images, Hyperlinks, Lists, Tables, Frames, HTML Forms. The need for CSS, Introduction to CSS, Basic syntax and structure, Inline Styles, Embedding Style Sheets, Linking External Style, Backgrounds, Manipulating Text, Margins and Padding, Positioning using CSS.

UNIT III. (Java Programming) Java Script, Introduction, Core features, Data types and Variables, Operators, Expressions, Functions, Objects, Array, Date and Math related Objects. JAVA Networking classes, TCP/IP Protocol Suite, File Transfer Protocol (FTP), Java Environment |Setup for Web Applications, JavaBean, Application Builder Tool, Bean Developer Kit (BDK), The Java Beans API, Introduction to EJB

UNIT IV. (Database) Database basics, SQL, MySQL, PostgreSQL, JDBC API, Driver Types, Two-tier and Three-tier Models, Connection Overview, Transactions, Driver Manager Overview, Statement Overview, Result Set Overview, Types of Result Sets, Concurrency Types, Prepared Statement Overview

UNIT V. (Java Applet and JSP) Java Web Programs and Applets, Web Application, Servlet, Servlet Life Cycle, Servlet Programming, Introduction to JSP, Life Cycle of a JSP Page, Translation and Compilation, Creating Static Content, Response and Page Encoding, Creating Dynamic Content, Using Objects within JSP Pages, JSP Programming

UNIT VI. (Dot Net Framework) Introduction to Dot Net, Dot Net framework and its architecture, CLR, Assembly, Components of Assembly, DLL hell and Assembly Versioning, Overview to C#, Introduction to ASP.net, Asp.net Programming

REFERENCE BOOKS

- J2EE: The complete Reference by James Keogh.
- Java EE and HTML5 Enterprise Application Development (Oracle Press) by John Brock, Arun Gupta, Geertjan Wielenga
- Struts: The Complete Reference, 2nd Edition by James Holmes

- ASP.NET Unleashed by Stephen Walther, Kevin Scott Hoffman, Nate Dudek
- Microsoft Visual C# 2013 Step by Step by John Sharp

GNU IMAGE MANIPULATION PROGRAMME

1. To familiarize the students with the underlying concepts of digital images.
2. To make the students know how to enhance images and prepare them for printing and publishing.

SYLLABUS **4 credits**

A. Theory

UNIT I Imaging Concepts and Graphic Formats: Pixel, Resolution, File Size, Image Compression, Raster & Vector Images, Color Model.

UNIT II Capturing and Creating Images: Saving Images, Scanning Images, Familiarization with GIMP Interface.

UNIT III Settings: Foreground and Background Colors, Grid Properties.

UNIT IV Image Manipulations: Resizing images, Cropping images, Moving and Copying images, Rotating and flipping images.

UNIT V Working with Text: Creating and editing text, Formatting Text, Applying text wraps.

UNIT VI Tools: Drawing tools, Painting tools.

REFERENCE BOOKS

- Kay Richter, GIMP 2.8- Buch (e-book)
- Olivier Lecarme and Karine Delvare, The Book of GIMP, A complete Guide to Nearly Everything, Kindle Edition

B. Practicum

Students are required to implement a project based on learned concepts.

7. Curriculum Alignment Matrix

Curriculum Alignment Matrix lists the learning objectives against the courses in the program and it becomes clear where assessment of student learning should occur. The curriculum alignment matrix becomes the basis of the assessment plan. With this, faculty and/or assessment coordinator can determine what student artifact or work sample (signature assignment or other assignment(s)) can be used to measure progress towards the learning objectives and/or when the assessment will take place. In addition, the matrix will help point out any gaps in the curriculum. The exercise of building and reviewing a curriculum alignment matrix encourages reflection on the curriculum and can lead to better integration among courses.

Curriculum Alignment Matrix is a table with one row for each learning outcome and one column for each course or required event/experience. Faculty identify where key learning outcomes are *introduced* (I), *reinforced* with the opportunity to practice (R or P), and where *mastery* (M) is achieved at the senior or exit level. When the matrix is complete, the program can identify where assessment evidence (A) should be gathered. In addition to courses, faculty should include any other required events/experiences (e.g., internships, department symposium, national licensure exams).

TABLE VI: Curriculum Alignment Matrix for BSc with Computer Science

Course Type	Course Name	PLO-									
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
CC-1A	Programming Methodology	I	I	-	I	-	-	I	-	I	-
CC-2A	Data Structures	R	-	-	R	-	I	I	-	-	-
CC-3A	Operating System	R	I	-	-	I	-	I	I	-	-
CC-4A	Database Management System	-	R	-	M	-	I	R	I	I	I
DSE-1A Any One	Software Engineering	M	R	-		I	I	R	I	I	-
	Computer Ethics	-	-	-	-	I	I	-	-	I	-
	Computer Organization &Architecture	I	I	-	-	-	I	-	I	-	-
	Computer Networks	-	M	I	-	R	R	I	R	-	I
DSE-2A Any One	Data Mining	M	-	-	M	-	R	M	-	-	R
	Internet of Thing	-	I	-	M	R	M	R	R	-	R
	Artificial Intelligence	M	-	I	-	-	M	R	-		R
	Computer Graphics	M	M	-	-	-	I	-	-	-	R
SEC-3A Any one	MATLAB Programming	R	M	-	R	-	R	I			
	Programming in Java	R	M	-	R	-	R	I	-	-	-
	Python Programming	R	M	-	R	-	R	I			
SEC-4A Any one	Web Programming	-	R	I	-	-	M	R	-	R	I
	Mobile Application Development	-	I	I	M	R	M	M	-	-	I
	Cloud Computing	-	R	I	M	R	M	M	-	-	I

TABLE VII: Curriculum Alignment Matrix for BSc (Hons) in Computer Science

	Course Name	**PLO-**														
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
	Prog Methodology	I	I	-	I	-	-	I	-	I	-	I	I	-	-	-
	Comp System Arch	I	I	I	-	I	-	I	I	I	-	-	-	-	-	-
	Data Structures	R	-	-	R	-	I	I	-	-	-	I	-	-	-	-
	Discrete Structure											-	-	-	-	-
	Operating System	R	I	-	-	I	-	I	I	-	-	I	I	-	-	-
	Algorithm	M	M	I	M	-	R	-	-	-	-	R	I	-	-	-
	Computer Graphics	M	M	-	-	-	I	-	-	-	R	-	I	-	-	-
	Computer Networks	-	M	I	-	R	R	I	R	-	I	R	I	-	-	-
CC	Software Engineering	-	R	-	M	-	I	R	I	I	I	I	I	-	-	-
	DBMS	-	R	-	M	-	I	R	I	I	I	R	I	-	-	-
	Object-Oriented Prog	R	M	-	R	-	R	I	-	-	-	I	I	-	M	M
	Internet Technologies	M	-	I	-	-	M	R	-	-	R	R	R	I	M	M
	Artificial Intelligence	M	-	I	-	-	M	R	-	-	R	M	M	R	M	M
	Computer Graphics	M	-	I	-	-	M	R	-	R	R	M	R	-		
	Machine Learning	M	-	M	-	-	M	M	-	-	R	M	M	M	M	M
	MATLAB Programming	R	M	-	R	-	R	I		I		-	I	I	I	I
SEC	Programming in Java	R	M	-	R	-	R	I	-	-	-	I	I	I	I	I
	Python Programming	R	M	-	R	-	R	I		-		-	I	I	I	I
	Web Programming	-	R	I	-	-	M	R	-	R	I	-	I	I	I	I

	Mobile Application Development	-	I	I	M	R	M	M	-	-	I	-	I	I	I	I
DSE	Cloud Computing	-	R	I	M	R	M	M	-	-	I	R	M	R	R	R
	Image Processing	M	-	R	-	-	M	R	-	-	R	M	M	R	M	M
	Data Mining	M	-	R	-	-	M	R	-	-	R	M	R	R	M	M
	Data Analytics	M	-	R	-	-	M	R	-	-	R	M	R	R	R	M
	Internet of Things	M	-	R	-	-	M	R	-	-	R	R	R	R	M	M

8. Teaching-Learning Process

The teaching-learning process should be in-line with the course objective and outcomes. Teaching has to ensure that the suggested outcomes are ensured for each course and overall programme. Teaching-aids should be used wherever required to facilitate proper and impactful learning. Blended learning is recommended with the use of MOOC platforms and classroom teaching.

To meet the set objectives of the course and enable students achieve the expected outcomes of the course the teaching-learning process should be appropriately chosen. Though the teachers are best positioned to create innovative models suitable for teaching the course, certain well accepted and widely tested processes are suggested to achieve the desired outcomes

CLASSROOM TEACHING - Regular classroom and face to face teaching and tutorialscan be primarily used for imparting theoretical foundations of Computer Science. Applications of the same may be explained from time to time so that the student can appreciate the theory.

LABORATORY - Lab exercises in programming and usage of package / software tools should be made mandatory and integral part. Open source software/Packages should be preferred over proprietary tools wherever available.

SEMINARS - Guest lectures and seminars involving industry experts and eminent teachers should be arranged to help the students understand the practices in the industry and developments in the field.

MOOCS - Teacher should choose appropriate lecture materials and videos on similar courses available online through Massive Open Courses Online in the world wide web (such as NPTEL) to provide good perspective of the course and usecases and promote blended learning.

PROJECT - Wherever possible the laboratory assignments can be designed in the form of a mini project. For example, the database course lab assignments can be designed to build a complete system for library management. Similarly, summer/ Semester breaks can be utilized for guiding students to develop live projects with industry orientation/ industry problem. Teamwork work should be encouraged,

(1) **ASSIGNMENTS -** Home assignments should be designed to make student collect information from various sources and solve unfamiliar problems and make comparisons of solutions

(2) **MAJOR PROJECT -** The major project should be defined based on the student proposals keeping in mind that opportunity to demonstrate the knowledge and skills gained during the course. One-One mentoring support should be provided.

(3) **Simulation -** Packages to provide simulated environments to teach various components of networking and hardware working should be used wherever feasible.

9. Assessment Methods

The committee recommends that assessment should be viewed not only merely as a testing by the institution to evaluate the students' progress, but also as a valuable tool for a student to learn what is expected of him/her, where their level of knowledge and skill is lacking, and perhaps most importantly, what he/she could do to improve these levels with the valuable inputs of the lecturers. Assessment methods are the strategies, techniques, tools and instruments for collecting information to determine the extent to which students demonstrate desired learning outcomes. In the Bachelor's programmes leading to degrees such as BSc with Computer Science and BSc(Hons) in Computer Science, the assessment and evaluation methods focus on testing the conceptual understanding of the basic ideas of computer hardware and software, development of programming skills and experimental techniques, retention and ability to apply the knowledge acquired to real-life applications, and to solve new problems and communicate the results and findings effectively. Based on the Learning Objectives defined for each course as proposed in detail, assessment methods can be designed to monitor the progress in achieving the Learning Objectives during the course and test the level of achievement at the end of the course. Several methods can be used to assess student learning outcomes. Relying on only one method to provide information about the program will only reflect a part of students' achievement.

Modular Assessment

As the courses are broken up into a smaller more cohesive learning outcomes a module will consist of a number of these smaller, finer grained assessments of which the majority can be considered to be formative assessments that aid the learning process rather than assessments aimed at solely being used to evaluate the student.

Continuous Assessment

The continuous assessment occurs on a regular and continuous basis, it is an ongoing formative and summative process, involves the monitoring of students, is integrated with teaching, involves a systematic collection of marks or grades into a final score, may be used to determine the students' final grades.

Direct methods of assessment ask students to demonstrate their learning while indirect methods ask students to reflect on their learning. Tests, essays, presentations, etc. are generally direct methods of assessment, and indirect methods include surveys and interviews. For each Learning Objective, a combination of direct and indirect assessment methods should be used.

Formative Assessment

While *formative assessment* is to gather feedback from formal or informal processes that can be used by the instructor and the students to gather evidence for the purpose of improving learning, *summative assessment* measures the level of success or proficiency that has been obtained at the end of an instructional unit, by comparing it against some standard or benchmark. Nevertheless, the outcome of a *summative assessment* can be used formatively when students or faculty use the results to guide their efforts and activities in subsequent courses. Daily programming assignments or home-assignments is a good way of implementing *formative assessment* and gives an idea of how well the students understood and could apply each programming concept. Another way of *formative assessment* can be that at the end of each class period, a student response system can be used to ask students one or more questions about the topic taught on that day. Regular tutorial Assignment, Term-paper, Seminar Presentation, Surprise Quizzes, Open-book Quizzes should be adopted for formative assessments. It is suggested that 25-30% weightage be given *Formative Assessments* in case of theory components while 30-40% weightage be given to the Programming/Laboratory/Projects/Dissertation components of the various courses.

During the semester, at least three smaller formative assessments shall be given for each course. To pass a course a student had to achieve marks between 70% in two of the assessment opportunities. The philosophy is that the student could fail one opportunity and take the experience gained from that opportunity to pass subsequent assessments.

Summative Assessment

For the traditional summative assessment, it is the semester tests based. The students need to attend two semester tests which consist of half of the content they learned for each test. Students are admitted to an examination for individual courses if they attain the minimum semester mark of 40%. Summative Assessment for the theory papers, can be a combination of Mid -Semester Test, Individual /Team Project report, Oral Presentations of Seminar/Projects, Viva -Voce Examination for dissertation and End Semester closed book examination. Summative Assessment methods shall be different for theory courses and Practical Courses.

It is suggested that the examination questions should be asked keeping the learning outcomes in mind and also covering all the Units. Term papers, problem solving assignments, Lab projects, Internship experience, group projects are recommended for achieving the expected outcomes. Wherever possible, students need to do minor projects in practical classes to learn the technology and also to apply the technology for problem solving. As this is a technology oriented programme and new technologies are introduced quite often, care should be taken to familiarize the students with the recent advances through seminars or term papers and case studies. This should be given due weightage during continuous evaluation process. To achieve this objective, the following are suggested

(i) The end examination papers should be covering all units of the syllabus. Questions should be balanced and evaluate the comprehension, analytical and problem-solving skills.

(ii) The students should be evaluated on teamwork in addition to the technical skills through projects.

(iii) Ability to self-learning and solving new problems should be assessed through assignments, Seminars and project work.

(iv) It is recommended that 25-30% weightage of marks shall be devoted for formative assessment.

(v) It is recommended that 40% weightage be given for practical and laboratory work.

(vi) Peer evaluation component is recommended for project evaluation and seminar.

(vii) Online course certification should be encouraged and equivalent grade for the same need to be worked to achieve the outcome of self-learning.

10. Keywords

Learning Outcome, Graduate Aptitude, Qualification Descriptor, Generic Elective, Skill Enhancement, Core Compulsory Courses, Discipline Specific Elective, Summative Assessment, Formative Assessment, Curriculum Alignment Matrix.

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