File Ref.No.Ac.A3/Faculty of Science/2023 (PART-I)

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

(Abstract)

Faculty of Science - Regulations for the Four Year Under Graduate Programme (FYUGP) and Five Year Integrated Post Graduate Programme (FYIPGP) effective from 2024 admission onwards - Resolution of the Academic Council - Communicated - Orders issued - reg.

ACADEMIC A SECTION

No.CUSAT/AC(A).A3/3587/2024 Dated,KOCHI-22,22.08.2024

Read:-Item No. I (g)(1) of the minutes of the meeting of the Academic Council held on 30.04.2024

ORDER

The Academic Council considered along with the recommendations of its standing committee, the Minutes of the meeting of Faculty of Science held on 08.04.2024 and resolved to approve the following:

1. ***Regulations for the Four-Year Under-Graduate programme (FYUGP) and Five-Year Integrated Post-Graduate Programme (FYIPGP) effective from 2024 admission onwards (Appendix I).***

These Regulations shall apply to the Five-Year Integrated M.Sc major in Biological Sciences/Five-Year Integrated M.Sc major in Chemistry/ Five-Year Integrated M.Sc major in Mathematics/ Five-Year Integrated M.Sc major in Physics/ Five-Year Integrated M.Sc major in Statistics/ Five-Year Integrated M.Sc major in Computer Science (Artificial Intelligence and Data Science)/ Five-Year Integrated M.Sc major in Photonics under the Faculty of Science and Faculty of Technology of the Cochin University of Science and Technology with effect from 2024 admissions.

2. ***The curriculum structure and syllabi of the following Five-Year Integrated M.Sc Post-Graduate programmes with effect from 2024 admissions:***

i. Five Year Integrated M.Sc major in Chemistry (Appendix II).
ii. Five Year Integrated M.Sc major in Biological Sciences (Appendix III).
iii. Five Year Integrated M.Sc major in Mathematics (Appendix IV).
iv. Five Year Integrated M.Sc major in Physics (Appendix V).
v. Five Year Integrated M.Sc major in Statistics (Appendix VI).

Orders are, therefore, issued accordingly.

Dr. V. Sivanandan Achari *

Registrar

To:

1. The Dean, Faculty of Science/Technology
2. Chairpersons, All BoS under Faculty of Science/ BoS in Photonics/Computer Science
3. The Heads concerned / Co-ordinator, Centre for Integrated Science
4. All AR/DR Examination wing - with a request to forward to concerned sections
5. The Director, IQAC/ DoA
6. CIRM/Conference Sections
7. PS To VC/PVC;PA To Registrar/CE.

* This is a computer generated document. Hence no signature is required.

Regulations of the Integrated M.Sc. programmes, April 2024

Cochin University of Science and Technology

(2024 Admission onwards)

PREAMBLE

These Regulations shall be called '**Regulations for the Four-Year Under-Graduate Programme (FYUGP) and Five-Year Integrated Post-Graduate Programme (FYIPGP)**'. These regulations will be part of the Five-Year Integrated M.Sc. Major in Biological Sciences/ Five-Year Integrated M.Sc. Major in Chemistry/ Five-Year Integrated M.Sc. Major in Mathematics/ Five-Year Integrated M.Sc. Major in Physics/ Five-Year Integrated M.Sc. Major in Statistics / Five-Year Integrated M.Sc. Major in Computer Science (Artificial Intelligence & Data Science)/ Five-Year Integrated M.Sc. Major in Photonics.

The regulations are designed to serve as a comprehensive resource for the preparation of curriculum for the Four-Year Under-Graduate (FYUG) and Five-Year Integrated Post-Graduate (FYIPG) programs. The regulations aim to provide a structured and comprehensive educational experience for students pursuing a specific academic degree. The document aims to facilitate a transformative process that ensures both the UG and PG programs will be student-centred, and aligned with the evolving needs of higher education and employment.

1. **Scope**

1.1. These regulations shall apply to the Five-Year Integrated M.Sc. Major in Biological Sciences/ Five-Year Integrated M.Sc. Major in Chemistry/ Five-Year Integrated M.Sc. Major in Mathematics/ Five-Year Integrated M.Sc. Major in Physics/ Five-Year Integrated M.Sc. Major in Statistics / Five-Year Integrated M.Sc. Major in Computer Science (Artificial Intelligence & Data Science)/ Five-Year Integrated M.Sc. Major in Photonics under the Faculty of Science and Faculty of Technology of the Cochin University of Science and Technology with effect from 2024 admissions.

1.2. The provisions herein supersede all other regulations with respect to the Five-Year Integrated M.Sc. in Biological Sciences/ Five-Year Integrated M.Sc. in Chemistry/ Five-Year Integrated M.Sc. in Mathematics/ Five-Year Integrated M.Sc. in Physics/ Five-Year Integrated M.Sc. in Statistics / Five-Year Integrated M.Sc. in Computer Science (Artificial Intelligence & Data Science)/ Five-Year Integrated M.Sc. in Photonics under the Faculty of Science and Faculty of Technology of the Cochin University of Science and Technology.

2. Definitions

2.1. **Department/School** means Department/School instituted in the University as per Cochin University of Science and Technology Statutes and Act.

2.2. **Credit** is the quantity of instruction given or the learning outcomes and a notional time to achieve those outcomes.

2.3. **Major** component is the subject that is the main focus of the study. By selecting a major, the student would be provided with an opportunity to pursue an in-depth study of a particular subject or discipline.

2.4. **Minor** component is a set of courses in a particular subject or a theme that complements the Major.

2.5. **Discipline Specific Course** is that focuses on a specific subject or field of study. These courses are designed to provide students with a deep understanding of the theories, concepts, and practices within a particular discipline.

2.6. **Discipline Specific Core (DSC)** is a course that should be pursued by a student as a mandatory requirement of his/her programme of study.

2.7. **Discipline Specific Elective (DSE)** is a course of a particular discipline that a student has the choice to select from a pool of such courses from his/her programme of study. The DSEs to offer in a program of study would be identified by the concerned Department/School.

2.8. **Capstone level courses** allow the students to demonstrate their cumulative knowledge in their field of study. It plays a vital role in preparing students for the world of work with practical applications, professional knowledge, and skills.

2.9. **Ability Enhancement Courses (AEC)** are the courses designed specifically to achieve competency in modern Indian/world languages and English with special emphasis on communication skills.

2.10. **Skill Enhancement Courses (SEC)** are designed to develop Creativity, Critical Thinking, Communication, and Collaboration, which are known as 21st-century skills.

2.11. **Value Addition Courses (VAC)** are the courses meant for personality development, perspective building and developing self-awareness of a graduate student.

2.12. **Multi-Disciplinary Courses (MDC)** are the courses intended to broaden the intellectual experience and to build a conceptual foundation about arts, science, commerce, language, and social sciences among students.

2.13. **Audit Course** means a course which can be opted by a student but which will not accrue any credit.

2.14. **MOOC Course** means a Massively Open Online Course offered by UGC, CUSAT or any other recognized educational agencies approved by the University.

3. Structure of FYUG and FYIPG Programmes

The new FYUGP and FYIPGP curriculum framework shall provide an overall redesign strategy to address the specific needs of the UG and PG programmes and, allow a systematic and evidence-based approach to curriculum transformation. The structure of the programmes shall assure quality and continuous improvement.

The programme pathways available for the students are the following.

3.1. **3-year UG Degree:** Students who wish to exit after 3 years of the program will be awarded a UG Degree in a Major discipline after the successful completion of three years, securing a minimum of 133 credits and satisfying the minimum course requirements as given in tables.

3.2. **4-year UG Degree (Honours):** A four-year UG Honours Degree in a Major discipline will be awarded to those who complete a four-year degree program securing a minimum of 177 credits and have satisfied the minimum course requirements as given in the tables. Honours students have to undertake a mini project/internship of 4 credits under a faculty member of the University/any higher education institution HEI)/research institution/industry in their fourth year of the programme.

3.3. **4-year UG Degree (Honours with Research):** Students who are highly motivated to opt for research as their career can choose honours with a research stream in the fourth year. They should do a research project or dissertation under the guidance of a faculty/Scientist of the University/ College/ Department/INIs/National Labs/Foreign Institutions of Higher learning or Research/R&D Laboratories of Industry as approved by the Department Council. The research project/dissertation shall be in the major discipline. The students who secure a minimum of 177 credits, including 12 credits from a research project/dissertation, are awarded a UG Degree (Honours with Research). The minimum requirement for a student to be considered for the 4-year UG Degree (Honors with Research) programme shall be CGPA 8.0 up to sixth semester. The number of seats and the exact selection criteria shall be fixed by the respective Department/School Council.

3.4. **5-year Integrated PG Degree:** A five-year PG Degree in a Major discipline will be awarded to those who complete a five-year post graduate degree program securing a minimum of 221 credits and have satisfied the minimum course requirements as given in the tables.

4. Possible Academic Pathways available for the students

In FYUGP, there are five possible structures or combinations, called **Academic Pathways**. Each pathway is defined by a specific combination of Discipline-Specific Courses.

4.1. **Single Major Pathway:** This pathway is recommended to those students who wish to do an in-depth study in a particular discipline without systematically exploring specific minor pathways.

4.1.1. The students pursuing FYUGP in a specific discipline shall be awarded a UG Degree in a Major discipline if they secure a minimum of 68 credits in that Major discipline (50% of the total credits of 133 required for the three-year programme).

4.1.2. The 26 credits (24 credits from different courses and 2 credits from Internship) in Discipline-Specific Courses can be acquired either from the same Major discipline or from other disciplines.

4.1.3. The students who have taken this pathway need to complete their 3 MDC courses from other disciplines.

4.1.4. If the students continue to the fourth year of FYUGP, to be eligible for a UG Honours Degree in the Major Discipline, they should earn a minimum of 36 credits in that Major discipline from Capstone level courses including a project, and an additional 8 credits from Major or other disciplines.

4.2. **Major with Minor Pathway:** This pathway is recommended to students who wish to do an in-depth study in more than one discipline with more focus on one discipline (Major) and relatively less focus on the other (Minor).

4.2.1. If students pursuing FYUGP are awarded a Major Degree in a particular discipline, they are eligible to be awarded a Minor in another discipline of their choice, if they earn a minimum of 27 credits (20% of the total credits of 133 required for the three-year programme) from six discipline-specific pathway courses (24 credits) and one Skill Enhancement Course (SEC) in that Minor discipline (3 credits).

4.2.2. The students who take this pathway need to complete their 3 MDC courses from disciplines different from their Major and Minor.

4.2.3. If they continue to the fourth year of FYUGP, to be eligible for a UG Honours Degree in their Major with a Minor, they should earn a further 8 credits from two courses in the chosen Minor discipline over and above the 27 credits earned in the first three years to have a total of 35 (27 + 8) credits in that Minor discipline (20% of the total credits of 177 required for the four-year programme).

4.2.4. The credit requirements for the Major discipline are the same as given for the Single Major Pathway.

4.3. **Major with Multiple Disciplines Pathway:** This pathway is recommended for students who wish to develop core competency in multiple disciplines of study. In this case, the credits for the minor pathway shall be distributed among the constituent disciplines/subjects.

4.3.1. If students pursuing FYUGP are awarded a UG Degree in a Major discipline, they are eligible to get mentioned their core competencies in other discipline(s) of their choice if they have earned 12 credits from the pathway courses of a particular discipline. In the first three years of FYUGP, this pathway is composed of one Major discipline with 68 credits, and maximum two other disciplines, with 12 credits from 3 courses in each discipline.

4.3.2. The students who have taken this pathway need to complete their 3 MDC courses from other than major and selected pathway disciplines.

4.3.3. If the students continue to the fourth year of FYUGP, to be eligible for a UG Honours Degree in the Major discipline, they should earn a minimum of 36 credits in that Major discipline from Capstone level courses including a project, and an additional 8 credits from Major or other disciplines.

5. **Curriculum Structure of the FYUGP**

The curriculum structure of FYUGP contains the following mandatory components.

5.1. General Foundation Components (4 major course baskets)

- Ability Enhancement courses (AEC)
- Skill Enhancement Courses (SEC)
- Value Addition Courses (VAC)
- Multi-Disciplinary Courses (MDC)

5.2. Discipline Specific Pathway Components (Major/Minor)

- Discipline Specific Core Course (DSC) (Level 100- 300)
- Discipline Specific Elective Course (DSE) (Level 300)
- (DSC courses at Level 100 are for building the foundations)

5.3. Discipline Specific Capstone Components.

- Advanced DSC and DSE Courses (Level 400, 500)
- Projects, field training, internship, community activity etc.
- (Any programmes to promote experiential learning)

6. **Credit Structure of the FYUGP and FYIPGP**

6.1. General Foundation Courses

6.1.1. It is mandatory for all the students who enrolled for an FYUG degree programme to acquire 39 credits from general foundation courses, which are classified into four different sub-categories (approximately 30% credit decided for the three-year programme).

6.1.2. General Foundation Courses can be grouped into 4 major baskets, namely (1) Ability Enhancement Courses (AEC), (2) Skill Enhancement Courses (SEC), (3) Value Addition Courses (VAC), and (4) Multi-Disciplinary Courses (MDC).

6.1.3. All these foundation courses are 3-credit courses.

6.1.4. The ability Enhancement Courses (AEC) and Skill Enhancement Courses can include practicum components as well.

6.1.5. The students have to complete 12 credits (4 courses) from AEC, 9 credits (3 courses) from SEC, 9 credits (3 courses) from VAC, and 9 credits (3 courses) from MDC as part of their UG Programme.

General Foundation Courses			
Sl. No.	Name of the General Foundation Course	No. of Courses	Required Credit
1.	Ability Enhancement Courses (AEC)	4	12
2.	Skill Enhancement Courses (SEC)	3	9
3.	Value Addition Courses (VAC)	3	9
4.	Multi-Disciplinary Courses (MDC)	3	9
	Total in the first three years of FYUGP	**13**	**39**

6.2. **Discipline-Specific Foundation and Pathway Courses for a 3-year Degree**

6.2.1. The student who wishes to exit with a degree after three years needs to acquire 94 credits (approximately 70% of the total 133 credits) from Discipline Specific pathway, and capstone level courses, decided for the three-year programme.

6.2.2. Each DSC has 4 credits. The credit distributions for each of the subcategories of DSCs in the first three years of UGP are given below.

Discipline Specific Foundation/Pathway Courses for 3-year UGP				
Sl. No.	Name of the Pathway Courses	No. of Courses	Required Minimum Credits	Possible Maximum Credits
1.	Major Pathway Courses	17	68	80
2.	Minor Pathway Courses	6 + 1*	24 + 3*	30
3.	Internship/Apprenticeship	1**	2	2
	Total	**23**	**94*** **	**112**

(* to be acquired from SEC offered in the Minor discipline; **not counted as a course; *** excluding the 3 credits of the SEC done in the Minor discipline)

6.2.3. The consolidated minimum requirement of credits in the 3-year UGP are given below.

Sl. No.	Categorization of Courses for all Programmes	Minimum Number of credits for the 3-year UG
1.	Major	68
2.	Minor (Multiple Discipline) Pathway	27* (12** + 12**)
3.	Multi-Disciplinary Courses	9
4.	Ability Enhancement Courses	12
5.	Skill Enhancement Courses	6 (9**)
6.	Value Addition Courses	9
7.	Summer Internship / field-based learning etc.	2***
	Total	**133**

* The students who opt for a Major with a Minor discipline has to acquire 27 credits from 6 courses of 4 credits each from Minor discipline with a total of 24 credits, and 3 credits from SEC of the minor discipline; **The students who opt for a Major with Multi-Disciplinary discipline(s) have to acquire 12 + 12 credits from 3 + 3 courses of 4 credits each from those multidisciplinary discipline(s); *** not counted as a course.

6.3. Discipline Specific foundation and Pathway courses for 4-year Honours Degree

6.3.1. The student who wishes to continue to the fourth year for the Honours degree, he/she should successfully complete 133 credits in the first 3 years and should acquire 44 credits during their fourth year, out of which 36 credits should be from the Major discipline at the advanced level and 8 credits can be from a Minor pathway.

6.3.2. For students opting for other pathways not involving a Minor, these 8 credits can be in the Major discipline or in any other discipline.

6.3.3. There are two pathways in the FYUGP. The students can either exit the FYUGP or can continue with the FYIPGP. In the first case, the students can either opt for the Four-Year Honours Degree or can opt for Four-Year Honours with Research Degree. Those who opt to continue with the FYIPGP shall also be awarded the Four-Year Honours Degree/Four-Year Honours with Research Degree, however, the certificate for the same shall be awarded after completion of FYIPGP.

6.3.4. For students who opt for Honours Degree or continue with FYIPGP, it is mandatory to complete a mini project of 4 credits in the fourth year.

6.3.5. For students who opt for Honours with Research Degree, it is mandatory to complete an original research project of 12 credits in the fourth year.

6.3.6. The eligibility for a student to be considered for the 4-year UG Degree (Honours with Research) programme shall be CGPA 8.0 up to sixth semester. The number of seats and the selection criteria shall be fixed by the respective Department Council.

The consolidated minimum requirement of credits in the FYUGP are given below.

Minimum Number of Credits				
Sl. No.	Categorization of Courses for all Programmes	Minimum Number of Credits Required		
		3-year UG	4-year UG Honours	4-year UG Honours with Research
1.	Major	68	100 (100 + 8*)	92 (92 + 8*)
2.	Minor (Multiple Discipline) Pathway	27 (12 + 12)	27 + 8 (12 + 12)	27 + 8 (12 + 12)
3.	Multi-Disciplinary Courses	9	9	9
4.	Ability Enhancement Courses	12	12	12
5.	Skill Enhancement Courses	6 (9)	6 (9)	6 (9)
6.	Value Addition Courses	9	9	9
7.	Summer Internship / field-based learning etc.	2*	2*	2*
8.	Mini Project/Research Project		4	12
	Total	**133**	**177**	**177**

The figures in brackets indicate the minimum credit requirements for the multidisciplinary pathway courses; *students who opted for multi-disciplinary pathway may acquire 8 credits from major or other disciplines ** not counted as a course.

6.4. **Discipline-Specific Courses in the Fifth Year of the FYIPGP**

6.4.1. Students aspiring to progress to the fifth year of the FYIPGP must first accomplish 177 credits in the Undergraduate Honours Degree pathway.

6.4.2. The curriculum structure of the 2-year PG programme should be meticulously tailored to mirror the FYUGP stream, ensuring a seamless transition and integration for the students.

6.4.3. The curriculum for the fifth year is designed to offer 7 to 12 courses, with a total of 44 credits.

Discipline Specific Courses in fifth year of Integrated PG			
Sl. No.	Name of the Pathway Courses	No. of Courses	Required Credits
1.	Major Advanced/Capstone/PG Level Courses (Ninth Semester)	5	20
2.	Research Project/ PG Level Courses (Tenth Semester)	1-5	20
3.	Courses in Online or blended mode (Ninth and Tenth Semesters)	1-2	4
	Total in the fifth year of FYPGP	**7-12**	**44**

6.5. Capstone Level Courses

The capstone level courses allow the students to demonstrate their cumulative knowledge in their field of study. Capstone level courses include topics on specialized/advanced level, internships, community engagement and services, vocational training, professional training, or other kinds of work experience.

6.5.1. **Advanced major (Specialization):** Advanced major courses include courses with a focused area of study attached to a specific major, which are optional in nature. These courses include courses on research methodology as well. These courses will help the graduates to deepen their knowledge in a particular area of study with more focus and direction.

6.5.2. **Summer Internship/Apprenticeship:** This promotes the induction into actual work situations. All students have to undergo internships/ apprenticeships in a firm, industry, or organization or training in labs with faculty and researchers in their own or other HEIs/research institutions during the summer term. Students will be provided with opportunities for internships with local industry, business organizations, health, and allied areas, local governments (such as panchayats, municipalities), Parliament or elected representatives, media organizations, artists, crafts persons, and agricultural sector, so that the students may actively engage with the practical side of their learning and, as a by-product, further improving their employability.

6.5.3. Internship has 2 credits, and it should be completed in the first three years of FYUGP. The firm /institution from which the student shall undergo internship should be prior-approved by the HoD/Department Council, after verifying the quality and genuineness of the firm/institution.

6.5.4. **Field-based learning/minor project:** Provides opportunities for students to understand the different socio-economic contexts. It will aim at giving students exposure to development-related issues in rural and urban settings.

6.5.5. **Community engagement and service:** Seeks to expose students to the socio-economic issues in society so that the theoretical learnings can be supplemented by actual life experiences to generate solutions to real-life problems.

6.5.6. **Vocational Education and Training:** The ever-changing global scenario makes the world more competitive and requires high levels of lateral thinking and the spirit of entrepreneurship to cope with emerging challenges.

6.6. **Signature Courses**

6.6.1. Each Department can design signature courses in DSE/SEC/VAC/ Vocational Courses offered by their faculty members, approved by the BoS or the academic committee.

6.6.2. A Department can empanel distinguished individuals who have excelled in their field of specialization like science and technology, industry, commerce, social research, media, literature, fine arts, civil services etc. as adjunct faculty as per the UGC guidelines with the approval of the University. With approval of the BoS or the academic committee, the adjunct faculty can offer DSE/SEC/ VAC/Vocational Courses as signature courses.

6.6.3. Guest faculty/Visiting faculty/Visiting Scholars can also offer DSE/SEC/VAC/ Vocational Courses as signature courses, approved by the BoS or the academic committee.

6.7. **Audit Course**

A student has the choice of auditing not more than one course in each semester. Students who desire to audit courses over and above the number of courses prescribed have to choose from amongst the courses offered by different Departments in that semester and inform their department in writing. Courses thus audited should also be indicated in the course Registration forms along with other courses opted for that semester.

6.8. **Credit Details**

The proposed number of credits per course and the credit distribution of them for the FYUGP and FYIPGP are given below:

6.8.1. A course that includes one hour of lecture or tutorial or a minimum of two hours of lab work, practical work, or field work per week is given one credit hour.

6.8.2. One credit in a semester should be designed for 15 hours of Lectures or Tutorials or 30 hours of practicum and learner engagement in terms of course-related activities such as seminar preparation, submitting assignments, etc.

6.8.3. A one-credit seminar or internship or studio activities or field work/ projects or community engagement and service will have two-hour engagements per week (30 hours of engagement per semester).

6.8.4. A course can have a combination of lecture credits, tutorial credits, and practicum credits, as

- (1) Lecture (L): Courses involving lectures
- (2) Tutorial (T): Courses involving problem-solving and discussions
- (3) Practicum or Laboratory (P): Course requiring students to participate in a project or practical or lab act Seminar: Course requiring structured discussion/conversation or debate focused on assigned tasks Internship: Course requiring actual work situations. Internships involve working with local industry, government etc. Studio activities: creativity artistic activities Field practice/projects: Learning in field Community engagement and service: expose students to the socio-economic issues in society.

6.8.5. A course should be of a minimum of 2 credits, and a maximum of 4 credits.

6.8.6. A student shall be able to opt for a certain number of extra credits over and above the requirements for the award of a Degree.

6.8.7. Maximum Number of credits that a student can earn per semester shall be restricted to 30. Hence a student shall have the option of acquiring extra credits to a maximum of 180 credits for a 6-semester UG program, and 240 credits for a 4-year (8-semester) UG program.

7. **Duration of programmes, credits requirements and options**

7.1. Students will be offered the opportunity to take breaks during the programme and resume after the break, but the total duration for completing the programme shall be as mentioned in 7.2.

7.2. Students may complete the undergraduate programme at a slower pace. They will be allowed to pursue a 3-year UG programme within a period of 5 years, 4-year UG programme within a period of 6 years, and FYIGP within a period of 7 years without obtaining readmission.

7.3. The University shall admit candidates not only for programmes, but also for courses, however, the admission is subject to the availability of seats in the respective departments.

7.4. The lateral entry for programmes in the odd semesters are allowed based on the admission rules of the University from time to time, and subject to the availability of seats in the concerned Department/School.

8. Academic Levels of Pathway Courses

The pathway courses shall be coded based on the learning outcomes, levels of difficulty, and academic rigor. The coding structure is as follows.

000–099: Prerequisite courses for a foundation/introductory course with no credits.

100–199: Foundation or Introductory courses that are intended for students to gain an understanding and basic knowledge about the subjects and help them decide the subject or discipline of interest. These Courses may also be a prerequisite for courses in the major subject. These courses generally focus on foundational theories, concepts, perspectives, principles, methods, and procedures for critical thinking to provide a broad basis for taking up more advanced courses.

Students of FYUGP may opt for a minimum of 24 credits at this level. These courses are taught in semesters 1 and 2 of FYUGP.

200–299: Intermediate-level courses, including Discipline-Specific Courses intended to meet the credit requirements for Major and Minor areas of learning. These courses can be a part of a Major and can be prerequisite courses for advanced-level Major courses.

Students of FYUGP may opt for a minimum of 32 credits at this level. These courses are taught in semesters 3 and 4 of FYUGP.

300–399: Higher-level courses which are required for majoring in a disciplinary/ interdisciplinary area of study for award of degree. These courses can be a part of the Major pathway and can be prerequisite courses for advanced-level Major courses.

Students of FYUGP may opt for a minimum of 38 credits at this level, including the 2 credits of Internship. These courses are taught in semesters 5 and 6 of FYUGP.

400–499: Advanced courses/Capstone level courses, which would include taught courses with practicum, first-year postgraduate degree level courses, seminar-based courses, term papers, research methodology, advanced lab experiments, software training, capstone projects, research projects, hands-on training, internship/apprenticeship projects at the undergraduate level, etc.

Students of FYUGP may opt for a minimum of 44 credits at this level, out of which 8 credits can be of the level 300-399 if they are Minor Pathway courses. These courses are taught in semesters 7 and 8 of FYUGP.

500--599: Courses at the first-year postgraduate degree level for a 2-year PG Degree programme.

600--699: Courses at the second-year postgraduate degree level for a 2-year PG Degree programme.

700--799 and above: Courses limited to doctoral students.

Academic Levels of Pathway Courses				
Sl. No.	Academic Level	Nature of the Courses	Implementation in FYUGP and FYIPGP	
			Semesters	Minimum credits required
1.	00-99	Prerequisites for Foundation Courses	-	-
2.	100 – 199	Foundation Level Courses	1 & 2	24
3.	200-299	Intermediate Level courses	3 & 4	32
4.	300-399	Higher Level Courses	5 & 6	38*
5.	400-599	Advanced/Capstone/First year PG level courses	7 & 8	44**
6.	600-699	Second-year PG-level courses in a two-year PG degree programme	9 & 10	
7.	700-799	Courses in a doctoral programme		

* Out of 38 credits, 2 credits are from Internship.

** In the case of students opting for a pathway with a Minor, 8 credits out of 44 can be of 300-399 level

9. Changing the Major, the Minor, and the Academic Pathway

9.1. The course structure should be such that, in the first two semesters, the student has the choice of attending courses in different disciplines through Major, Minor and MDC. The student also has the choice of attending online courses in any discipline from repositories approved by the Board of Study.

9.2. At the end of the second semester, the student has the choice of changing the Major and Minor disciplines, and the academic pathway chosen at the time of admission. In that case, the new Major should be one of the disciplines in which minimum two courses should be attended in-person by the student, and in which minimum 8 credits should be already earned by the student. However, the change of minor to major shall be allowed subject to the availability of seats in the Department concerned.

9.3. It is also possible to change the Major to a discipline in which a minimum two courses as MDC are already attended in-person by the student in the first two semesters. In this case, only 6 credits are earned by the student by attending in-person the two MDC in any single discipline. In such a case, the student has to earn an additional 2 credits in the major discipline from any online courses through repositories approved by the Department Council.

9.4. Throughout the first two semesters, the academic advisor should guide the student to properly plan for the change of Major and academic pathway.

9.5. When a student changes the Major to one of the disciplines in which he/she has earned a minimum of 8 credits as a Minor or as a combination of MDC and online courses, the credits acquired by the student by these courses will be transferred to the total credits required for the new Major.

9.6. The student who switches to a new discipline in a broad stream different from the one to which he/she originally sought admission should be equipped to learn that new discipline. To ensure that such a student has acquired the prerequisite knowledge and skill set needed for the new discipline, each BoS should specify the minimum credits to be earned from the prerequisite courses of level 0-99 in that discipline. If the student has not learned these courses at the higher secondary level, he/she should do them online mode during the first two semesters. The credits earned from the prerequisite courses will not be added to the credits earned in the FYUGP.

10. **Admission**

The students are admitted to any of the following departments/schools which offer FYIPGP as per their choice through the Common Admission Test of the University.

Department/School	Academic Pathways Offered
Department of Applied Chemistry	Chemistry (Major, Minor, Multi-Disciplinary)
Department of Biotechnology	Biological Sciences (Major, Minor, Multi-disciplinary)
Department of Mathematics	Mathematics (Major, Minor, Multi-Disciplinary)

Department of Physics	Physics (Major, Minor, Multi-Disciplinary)
Department of Statistics	Statistics (Major, Minor, Multi-Disciplinary)
Department of Computer Science	Computer Science (Artificial Intelligence & Data Science) (Major, Minor, Multi-Disciplinary)
International School of Photonics	Photonics (Major, Minor, Multi-Disciplinary)

10.1. **Eligibility and Entrance Examination**

10.1.1. Candidates with **60% marks or 6.5 CGPA in the Plus Two examination** of the state of Kerala or any other examination accepted as equivalent thereto can apply, satisfying the following conditions.

Programme of Study	Eligibility
Five-Year Integrated M.Sc. in Biological Sciences	60% marks or 6.5 CGPA in the qualifying examination with Biology, Physics and Chemistry as subjects
Five-Year Integrated M.Sc. in Chemistry	60% marks or 6.5 CGPA in the qualifying examination with Mathematics, Physics and Chemistry as subjects
Five-Year Integrated M.Sc. in Mathematics	60% marks or 6.5 CGPA in the qualifying examination with Mathematics, Physics and Chemistry as subjects
Five-Year Integrated M.Sc. in Physics	60% marks or 6.5 CGPA in the qualifying examination with Mathematics, Physics and Chemistry as subjects
Five-Year Integrated M.Sc. in Statistics	60% marks or 6.5 CGPA in the qualifying examination with Mathematics, Physics and Chemistry as subjects
Five-Year Integrated M.Sc. in Computer Science (Artificial Intelligence & Data Science)	60% marks or 6.5 CGPA in the qualifying examination with Mathematics, Physics and Chemistry as subjects
Five-Year Integrated M.Sc. in Photonics	60% marks or 6.5 CGPA in the qualifying examination with Mathematics, Physics and Chemistry as subjects

10.1.2. Students shall register their major option for the preferred programme of study *i.e.*, Five-Year Integrated M.Sc. Major in Biological Sciences/ Five-Year Integrated M.Sc. Major in Chemistry/ Five-Year Integrated M.Sc. Major in Mathematics/ Five-Year Integrated M.Sc. Major in Physics/ Five-Year Integrated M.Sc. Major in Statistics / Five-Year Integrated M.Sc. Major in Computer Science (Artificial Intelligence & Data Science)/ Five-Year Integrated M.Sc. Major in Photonics at the time of submission of the application.

10.1.3. The rules in force regarding the relaxation in qualifying marks/grades and the reservation in admission shall be applicable to candidates belonging to the reservation categories.

10.2. **Entrance Examination**

10.2.1. The admission to the Five-Year Integrated M.Sc. Major in Biological Sciences/ Five-Year Integrated M.Sc. Major in Chemistry/ Five-Year Integrated M.Sc. Major in Mathematics/ Five-Year Integrated M.Sc. Major in Physics/ Five-Year Integrated M.Sc. Major in Statistics / Five-Year Integrated M.Sc. Major in Computer Science (Artificial Intelligence & Data Science)/ Five-Year Integrated M.Sc. Major in Photonics will be through the Common Admission Test examination (CAT) of CUSAT conducted by the Directorate of Admissions, CUSAT.

10.2.2. The students applying for the Five-Year Integrated M.Sc. Major in Chemistry/ Five-Year Integrated M.Sc. Major in Mathematics/ Five-Year Integrated M.Sc. Major in Physics/ Five-Year Integrated M.Sc. Major in Statistics / Five-Year Integrated M.Sc. Major in Computer Science (Artificial Intelligence & Data Science)/ Five-Year Integrated M.Sc. Major in Photonics have to write the entrance examination with Test code 101.

10.2.3. The students applying for Five-Year Integrated M.Sc. Major in Biological Sciences shall write Test Code 104.

10.2.4. The patterns of Test Codes 101 and 104 are given as follows.

Subject	
Test Code 101	Test Code 104
Physics	Physics
Chemistry	Chemistry
Mathematics	Biology

10.2.5. The scheme of the test shall be devised by the Directorate of Admissions and announced through the admission prospectus.

10.2.6. While preparing the Selection List, if tie arises, the following criteria shall be followed, one after the other, to resolve the ties, when more than one candidate secures the same total marks in the entrance examination:

Rank list for Five-Year Integrated M.Sc. Major in Biological Sciences

(a) The rank list for Five-Year Integrated M.Sc. Major in Biological Sciences shall be prepared from the test code 104 who opted for the Five-Year Integrated M.Sc. Major in Biological Sciences programme. Total marks of Physics, Chemistry, and Biology will be ranked in the order.

(b) For Tie Breaking in Five-Year Integrated M.Sc. Major in Biological Sciences rank list, marks obtained for Biology will be considered first.

(c) If the tie continues the number of correct answers scored in Biology will be counted.

(d) If the tie continues after applying the above two conditions, the date of birth of the candidates in the descending order (older to younger) will be considered.

(e) If the tie continues after applying the above three conditions, the names of the candidates in alphabetical order will be considered.

Rank list for Five-Year Integrated M.Sc. Major in Chemistry

(a) The rank list for Five-Year Integrated M.Sc. Major in Chemistry shall be prepared from the test code 101 who opted for the Five-Year Integrated M.Sc. Major in Chemistry programme. Total marks of Physics, Chemistry, and Mathematics will be ranked in the order.

(b) For Tie Breaking in Five-Year Integrated M.Sc. Major in Chemistry rank list, marks obtained for Chemistry will be considered first with higher marks given preference.

(c) If the tie continues the number of correct answers scored in Chemistry will be considered next.

(d) If the tie continues after applying the above two conditions, the date of birth of the candidates in the descending order (older to younger) will be considered.

(e) If the tie continues after applying the above three conditions, the names of the candidates in alphabetical order will be considered.

Rank list for Five-Year Integrated M.Sc. Major in Physics/ Five-Year Integrated M.Sc. Major in Photonics:

(a) The rank list for Five-Year Integrated M.Sc. Major in Physics/ Five-Year Integrated M.Sc. Major in Photonics shall be prepared from the test code 101 who opted for the Five-Year Integrated M.Sc. Major in Physics/ Five-Year Integrated M.Sc. Major in Photonics programme. Total marks of Physics, Chemistry, and Mathematics will be ranked in the order.

(b) For Tie Breaking in Five-year Integrated M.Sc. Physics/Five-Year Integrated M.Sc. Photonics rank list, marks obtained for Physics will be considered first with higher marks given preference.

(c) If the tie continues the number of correct answers scored in Physics will be considered next.

(d) If the tie continues after applying the above two conditions, the date of birth of the candidates in the descending order (older to younger) will be considered.

(e) If the tie continues after applying the above three conditions, the names of the candidates in alphabetical order will be considered.

Rank list for Five-Year Integrated M.Sc. Major in Mathematics/ Five-Year Integrated M.Sc. Major in Statistics/ Five-Year Integrated M.Sc. Major in Computer Science (Artificial Intelligence & Data Science):

(a) The rank list for Five-Year Integrated M.Sc. Major in Mathematics/ Five-Year Integrated M.Sc. Major in Statistics/ Five-Year Integrated M.Sc. Major in Computer Science (Artificial Intelligence & Data Science) shall be prepared from the test code 101 who opted for the M.Sc. Major in Mathematics/ Five-Year Integrated M.Sc. Major in Statistics/ Five-Year Integrated M.Sc. Major in Computer Science (Artificial Intelligence & Data Science) programmes. Total marks of Physics, Chemistry, and Mathematics will be ranked in the order. There shall be a separate rank list for the Mathematics, Statistics and Computer Science (Artificial Intelligence & Data Science) programmes.

(b) For Tie Breaking in the Five-Year M.Sc. Major in Mathematics/ Five-Year Integrated M.Sc. Major in Statistics/ Five-Year Integrated M.Sc. Major in Computer Science (Artificial Intelligence & Data Science) rank list, marks obtained for mathematics will be considered first with higher marks given preference.

(c) If the tie continues the number of correct answers scored in Mathematics will be considered next.

(d) If the tie continues after applying the above two conditions, the date of birth of the candidates in the descending order (older to younger) will be considered.

(e) If the tie continues after applying the above three conditions, the names of the candidates in alphabetical order will be considered.

11. **Course Registration and Attendance**

11.1. The Integrated M. Sc. Programmes are conducted in conformity with the attributes of the Outcome Based Education (OBE) and Choice Based Credit System (CBCS). The syllabi of all academic programmes are to be prepared in such a way that they contain the OBE attributes such as Programmes Outcomes (POs), Programme Specific Outcomes (PSOs), Course Outcomes (COs), course prerequisites, credits etc.

11.2. Students have to choose their academic pathway as specified in Section 4 of the Regulations and register for the courses of their choice within a week of the commencement of the first semester. Before commencement of each semester, the students have to choose and register their courses as per the minimum requirements of FYUGP and FYIPGP. From second semester onwards, the departments shall ensure the availability of seats for various discipline specific courses under Minor/Multi-Disciplinary pathways so that students who have taken these pathways will not have any difficulty in fulfilling their minimum credit requirements. Additional seats for the same courses may be allotted on a first-come-first-serve basis.

11.3. All students have to register for the general foundation and core courses. They can choose the elective courses of their choice in consultation with their mentors.

11.4. The student can drop/re-register any elective/audit course(s) within 15 working days after the commencement of the classes.

11.5. The students can choose MOOC courses from CUSAT, SWAYAM or other platforms as approved by the Department Council from time to time.

11.6. The course registration and provision for credit transfer for the credits acquired from the MOOC/SWAYAM platform shall be as per the general rules and regulations for MOOC courses issued by the university from time to time.

11.7. A minimum of 75% attendance is compulsory for the continuous evaluation and the End semester examination. The university may condone the shortage of attendance on valid grounds as per the existing university rules.

12. **Evaluation**

12.0.1 The final result in each course will be determined on the basis of continuous assessment and performance in the end semester examination which will be in the ratio of 50:50 in the case of theory courses.

12.0.2 The faculty handling the course shall be responsible for evaluating all the components of Continuous Assessment (CA).

12.0.3 For Laboratory Courses (Practical Courses), Open Ended Laboratory Courses, Mini project work and Final semester project work there shall be only Continuous Assessment (CA) as per procedures laid down by the Department Council of the department offering the programme.

12.0.4 For the Open-Ended Laboratory Courses, Mini project work and Final semester project work at the end of the Semester, the Students will have to submit a report of the work done; they will present the results in a Seminar and should defend the work in a Viva-Voce.

12.1. **Continuous Assessment (CA)**

The CUSAT has a scheme of rigorous and continuous internal assessment.

12.1.1. Written exams shall be precisely designed using a variety of tools and processes (e.g., constructed responses, open-ended items, multiple-choice with more than one correct answer), and the students should be informed about the evaluation modalities well in advance.

12.1.2. The time schedule for the CA and the nature of tests/assignments/quizzes that are relevant to the course may be followed. The specific nature of the assignments/tests will be described by the faculty in the class and can vary from course to course.

12.1.3. The student shall be given a minimum of two tests per semester in each course.

12.1.4. The faculty concerned can choose the mode of evaluation and compilation of final marks of CA ensuring all modules in the course syllabus covered in the assessment process with the approval of the department council.

12.1.5. The marks obtained in the continuous assessment shall be displayed on the notice board of the Department and grievances if any may be addressed to the respective Head of the Department. The Department Council which offers the concerned programme/course shall finalize the marks of the continuous assessment of each course after addressing such grievances.

12.2. **End-semester Examination (ESE)**

12.2.1. A final examination at the end of the semester in each course will follow the internal assessments during the semester. The end semester examination shall cover the entire syllabus of the course.

12.2.2. The question paper for the end semester examination for each course is to be set by the concerned course teacher in advance, which must be scrutinized by a committee, consisting of one or two faculties, who are competent in the subjects/course regarding, appointed by the Head/department council to ensure that questions are within the scope of the syllabus and also the entire syllabus of the course is fairly covered in the question paper. Modifications suggested by this committee should be reflected in the final question paper.

12.2.3. There shall be only a single internal evaluation for the end semester examination. Immediately after the examination is over, course teachers shall complete the evaluations and the results shall be finalized within 10 working days after the last examination is over so as to enable students who have failed to appear for the makeup examination.

12.2.4. The marks and grades in all the subjects obtained by the students have to be displayed on the notice board and the answer scripts can be made available to the students for scrutiny if necessary.

12.2.5. The final result in each course is calculated on the basis of continuous assessment and performance in the end-semester examination.

12.2.6. For End Semester Examination, the students have to score a minimum of 40% marks to get a pass. Also, the students should get a total of 50% marks for each course (Sum of CA and ESE) to get a pass in the course.

12.2.7. Heads of the Departments shall publish the marks obtained by the students, in the continuous assessment and end semester examination.

12.2.8. If the student has any grievance about the result of a course the student can approach the concerned Head of the Department and submit his/her grievance with supporting documents/arguments. The teacher, and the Head of the Department offering the course will examine the case and decide on his/her grievance. If the student is not convinced with the decision, he/she can approach the appellate authority, which is the department council of the department offering the programme to which the student is admitted. The appellate authority shall examine the grievance and take a final decision which must be intimated to the student in writing. The decision of the appellate authority shall be final.

12.2.9. The final marks and grades obtained by the students shall be published on the notice board. Those who could not obtain 40% marks in the End semester examination and 50% marks (Grade D) in total for a course will be declared as failed in that course.

12.2.10. Those who fail in any core or elective course shall approach the Head of the Department if necessary for a makeup examination. Within one week of the display of the results on the notice board, the Head of the Department with the help of the course teacher shall conduct an additional end semester examination for these candidates. This makeup is only to enable the student to pass the examination so by completing the course successfully.

12.2.11. If he/she completes the course successfully making use of this additional chance, he/she will be awarded only a D grade for that course. If student does not appear for the makeup examination, the he/she can appear for the supplementary examination next year.

12.2.12. **Supplementary Examination:** The students, who after completion of the prescribed duration of the course, are left with backlogs, are eligible to appear for supplementary exams.

12.2.13. The results of the examinations will be finalized and published by the Department council of the department offering the programme within 30 days of the last examination of the semester and the minutes shall be sent to the controller of examinations to issue the mark list of that examination.

12.3. **Backlogs**

No student of the FYUGP and FYIPGP shall be allowed to move to the 3rd, 5th or 7th semester, if he/she does not satisfy the following conditions.

Promotion to	Minimum number of credits to be earned
III Semester	Half of the total credits registered for Semester I
V Semester	Half of the total credits registered for Semesters I, II, & III put together
VII Semester	Pass all the registered courses up to Semesters VI

12.3.1. The students, who after completion of the prescribed duration of the six semesters, are left with backlogs, are eligible to appear for special supplementary examinations for their odd semester courses.

12.4. **Readmission**

12.4.1. The students who are not eligible for promotion to the next higher semester as per rules will be given opportunities to clear the backlogs in the previous semesters by appearing for supplementary examinations.

12.4.2. Once the student gets eligibility for promotion to the higher semester, he/she will be given re-admission along with the junior regular batch and can further continue his/her studies as a regular student from the semester where he/she is re-admitted.

12.4.3. This will be subject to the maximum period available for the completion of the course permitted by these regulations.

12.4.4. Re-admission under the above provision shall be permitted only once.

12.5. **Exit Option**

The option of an exit with a 3-year Bachelor's degree/4-year Bachelor's Degree with Honours/4-year Bachelor's degree with Honours (Research) shall be available for desiring students. The distinguishing features of the exit option are:

12.5.1. **Exit with 3-year UG Degree**

(a) The Exit Option with 3-year UG Degree will be available at the end of three years of the FYIPGP students.

(b) Students who seek to opt out after 3 years (six semesters) should have passed all the courses of the preceding six semesters. For exercising the Exit Option, the students should have secured a minimum of 133 Credits in toto for semesters 1-6.

(c) The students who exercise the Exit Option have to surrender the Mark lists of the previous semesters and pay a cancellation fee as per the rules of the University. They will be issued new mark lists in conformity with the 3-year UG Degree that will be conferred to them.

12.5.2. **Exit with 4-year UG Honours Degree**

(a) The Exit Option with 4-year UG Honours Degree will be available at the end of Four years for the FYIPGP students.

(b) Students who seek to opt out after 4 years (eight semesters) should have passed all the courses of the preceding eight semesters. For exercising the Exit Option, the students should have secured a minimum of 177 Credits in toto for semesters 1-8.

(c) The students who exercise the Exit Option have to surrender the Mark lists of the previous semesters and pay a cancellation fee as per the rules of the University. They will be issued new mark lists in conformity with the 4-year UG Honours Degree that will be conferred to them.

12.5.3. **Exit with 4-year UG Honours (Research) Degree**

(a) The Exit Option with a 4-year Honours Degree will be available at the end of Four years for the FYIPGP students. The eligibility for a student to be considered for the 4-year UG Degree (Honors with Research) programme shall be a CGPA of 8.0 up to the sixth semester. The number of seats and the selection criteria shall be fixed by the respective Department Council.

(b) A student who opts for a 4-year Honours (Research) Degree should have to undertake a research project in the department. If opportunities are available, the respective department council may permit the candidate to undertake the research project in other departments for research on interdisciplinary themes/National Laboratories/ Institutes of National Importance/ Industrial R & D Laboratories to earn a minimum of 12 Credits. For exercising the Exit Option, the student should have secured a minimum of 177 Credits in toto for semesters 1-8.

(c) The students who exercise the Exit Option have to surrender the Mark lists of the previous semesters and pay a cancellation fee as per the rules of the University. They will be issued new mark lists in conformity with the 4-year Degree Honours (Research) that will be conferred to them.

12.6. **Merger with the 2-Year PG**

In the Fourth Year, students of the FYUGP may be integrated with the students admitted for the 2-Year PG programme offered by the respective Departments to which they are admitted. After the merger *i.e.*, from 7th semester, any provision under this regulation inconsistent with the PG regulations in force for FYIPGP shall not be applicable and the respective provision under PG regulation shall prevail.

12.7. **Grade Card**

The University under its seal shall issue a Grade Card to the students on completion of each semester. The Grade card shall contain the following:

a) Title of the course taken as core, elective and audit. (An audit course shall be listed only if the student has secured a pass).

b) The credits associated with and the grades awarded for each course.

c) The number of credits (core and elective separately) earned by the student and the Grade point Average.

d) The total credits (core and elective) earned till that semester.

e) The evaluation of FYUGP and FYIPGP is done under the Grading System. There will be 7 letter grades; S, A, B, C, D and F on a 10-point scale which carries 10, 9, 8, 7, 6, 0 grade points respectively.

Computation of SGPA/CGPA: The following grades will be awarded based on the overall performance in each course.

Range of Marks*	Grades	Grade Points (G_i)
90 - 100	O - Outstanding	10
80 - 90*	A - Excellent	9
70 - 80*	B - Very Good	8
60 - 70*	C - Good	7
50 - 60*	D - Satisfactory	6
Below 50	F - Fail	0
	Ab - Absent	0

(*where X −Y range denotes X inclusive and Y exclusive)

The following is the procedure to compute the Semester Grade Point Average (SGPA) and Cumulative Grade Point Average (CGPA).

(i) The SGPA is the ratio of the sum of the product of the number of credits with the grade points scored by a student in all the courses taken by a student and the sum of the number of credits of all the courses undergone by a student, *i.e.*,

$$\text{SGPA(Si)} = \sum(C_i \times G_i) / \sum C_i$$

where C_i is the number of credits of the *i*th course and G_i is the grade point scored by the student in the *i*th course.

(ii) The CGPA is also calculated in the same manner taking into account all the courses done by a student over all the semester of a programme, i.e.,

$$\text{CGPA(Si)} = \sum(C_i \times S_i) / \sum C_i$$

where S_i is the SGPA of the *i*th semester and C_i is the total number of credits in each semester.

Classification for the Degree will be given as follows:

Classification for the Degree	CGPA
First Class with distinction	8.0 and above
First Class	6.5 – 8.0*
Second Class	6.0 – 6.5*

(*where X - Y range denotes X inclusive and Y exclusive)

(iii) The Grade Card issued at the end of the final semester shall contain the details of all the courses taken which shall include the titles of the courses, the credits associated with each course, the CGPA and the class. The rank shall be awarded based on CGPA corrected to the 2nd Decimal.

13. **Degrees Awarded to FYUGP and FYIPGP**

After successful completion of FYUGP or FYIPGP, the degrees in respective subject(s) will be awarded to the students.

(i) The format of the 3-year UG Degree shall be ‘Bachelor of Science Major in [subject]’ for Single Major Pathway; ‘Bachelor of Science Major in [subject] with Minor [subject]’ for Major with Minor Academic Pathway; and ‘Bachelor of Science Major in [subject] with [subject], [subject]’ for Major with Multiple Discipline(s) Academic Pathway.

(ii) The format of the FYUG (Honours) Degree shall be 'Bachelor of Science (Honours) Major in [subject]' for Single Major Pathway; 'Bachelor of Science (Honours) Major in [subject] with Minor [subject]' for Major with Minor Academic Pathway; and 'Bachelor of Science (Honours) Major in [subject] with [subject], [subject]' for Major with Multiple Discipline(s) Academic Pathway.

(iii) The format of the FYUG (Honours with Research) Degree shall be 'Bachelor of Science (Honours with Research) Major in [subject]' for Single Major Pathway; 'Bachelor of Science (Honours with Research) Major in [subject] with Minor [subject]' for Major with Minor Academic Pathway; and 'Bachelor of Science (Honours with Research) Major in [subject] with [subject], [subject]' for Major with Multiple Discipline(s) Academic Pathway.

(iv) The format of the FYIPG Degree shall be 'Master of Science in [subject]', irrespective of the Academic Pathway the student has chosen.

(iv) On successful completion of FYIPGP, students will be awarded FYIPGP Degree certificates as mentioned in Clause 13(iv) and their respective 3-Year Under-Graduate Degree certificates as mentioned in Clause 13(i). The students have to give separate applications forms for getting their Four-Year (Honours and Honours with Research) Under-Graduate Degree certificates, as mentioned in Clause 13(ii) and 13(iii).

14. **Mentoring, Tutorial and Remedial classes**

A system of mentoring by a teacher for a group of 5 students shall be coordinated by respective departments/schools. Mentors shall conduct orientation sessions to plan studies, utilize library and other common university and departmental resources. Mentors shall monitor academic progress of their mentee and identify weak learners in advance and arrange for remedial sessions in association with Centre for Integrated Studies (CIS) /Equal opportunity cell as the case may be. Special talents of their mentee may be identified and given guidance to nurture them. Mentors in association with CIS/Department shall coordinate internships/summer research programs/vacation activity during vacation months.

15. **Transitory Provisions**

Notwithstanding anything contained in these regulations, the Vice Chancellor shall, for a period of one year from the date of coming into force of these regulations, have the power to provide by order that these regulations shall be applicable to any programme with such modifications as may be necessary.

DEPARTMENT OF APPLIED CHEMISTRY

Scheme of Examination and Syllabus for the Five-Year Integrated M.Sc. Chemistry

(From 2024 admission onwards)

Approved by the Combined Board of Studies in Physical and Mathematical Sciences and Chemical and Biological Sciences on 4th April 2024

Cochin University of Science and Technology
Kochi-22

Preamble

Department of Applied Chemistry was established in 1976 with the support of UGC. Throughout the last few decades, the Department has continued to instill a scientific spirit in the students and impart strong basic theoretical and experimental skills to students. The department has always been keen to pave the path for high-quality education ensuring best career opportunities for the students. The Department is steadfast in its resolve to inculcate a spirit of continuous learning and social skills in the students, to kindle creative ideas and to equip them to face the future challenges in an enthusiastic manner.

The 5-Year Integrated M.Sc. Chemistry offered by the Department of Applied Chemistry is a trans-disciplinary non-professional course designed with an outcome-based syllabus which ensures that the students assimilate the subject in totality and can take it to further levels of application and creativity wherever required. The syllabus offers a flexibility of programme structure while ensuring that students get a strong foundation and gains indepth knowledge in chemistry. The first three Semesters provide an opportunity to cover the fundamentals in different science disciplines depending on the interests of students. From the fourth semester the students will undergo specialized courses in chemistry. The programme emphasizes the development of practical and analytical skills in students. The curriculum offers wide opportunities to specialize in their respective areas of interest along with acquiring practical skills. An entire semester dedicated to project work in institutes of national repute ensures wide scientific exposure to students and evokes research interest in advanced topics of current relevance.

Program Outcomes: Integrated M.Sc.

PO 1: Demonstrate a comprehensive understanding of fundamental principles and concepts in basic sciences.

PO 2: Analyse, evaluate, and synthesize complex scientific information and data using appropriate methods and techniques.

PO 3: Apply scientific reasoning and critical thinking adeptly to recognize, assess, and resolve problems encountered in various scientific and technological contexts.

PO 4: Utilize computational power, programming languages, and modern technologies proficiently to address scientific challenges, effectively integrating technological solutions into problem-solving processes.

PO 5: Achieve proficiency in using modern scientific tools and technologies for experimentation, data collection, analysis, and interpretation.

PO 6: Adhere to ethical principles and practices in the conduct of scientific research and professional activities, and work collaboratively with others.

PO 7: Engage in lifelong learning and professional development to enhance the knowledge and skills in basic sciences.

Program Specific Outcomes: Integrated M.Sc Chemistry

PSO 1: Acquire a systematic and coherent awareness of fundamentals and its applications in problem solving, and analytical and critical rationalizations.

PSO 2: Attain a firm grip on the basic and advanced principles of experimental/instrumental methods of analysis, and to execute them suitably for an in-depth analysis of chemical problems..

PSO 3: Acquire skills to design and perform scientific experiments and to accurately record and analyze the experimental results.

PSO 4: Acquire overall core competency in the subject and acquire skills for employment in academia and industry.

PSO 5: Acquire knowledge relevant to cater to the needs of present day society in the local/national/global arena.

PSO 6: Impart research and professional skills to undertake academia/industrial assignments by inculcating the spirit of team work, innovation and entrepreneurship

Academic pathways offered by Department of Applied Chemistry

Chemistry Major:

3-year UG Program: To earn a Chemistry Major in a 3-year UG Program, a student must complete a minimum of 68 credits in Chemistry, out of which 60 credits shall be from mandatory core courses (DSC) and 8 credits from elective (DSE) courses.

4-year UG Program (Honours): To earn a Chemistry Major in a 4-year UG Program (Honours), a student must complete a minimum of 104 credits in Chemistry, out of which 84 credits shall be from DSC courses and 16 credits from DSE courses and 4 credits from mini project.

4-year UG Program (Honours with Research): To earn a Chemistry Major in a 4-year UG Program (Honours with Research), a student must complete a minimum of 104 credits in Chemistry, out of which 84 credits shall be from DSC courses and 8 credits from DSE courses and 12 credits from a research project.

Chemistry Minor:

3-year UG Program: To earn a Minor in Chemistry in a 3-year UG Program, a student must complete a minimum of 27 credits in Chemistry, out of which 24 credits shall be from DSC courses and 03 credits from an SEC elective.

4-year UG Program: To earn a Minor in Chemistry in a 4-year UG Program, a student must complete a minimum of 35 credits in Chemistry, out of which 24 credits shall be from mandatory DSC courses, 3 credits from an SEC elective 8 credits from DSE courses.

Discipline mention in Chemistry:

To earn a Discipline mention in Chemistry in a UG Program (3 or 4 years), a student must complete a minimum of 12 credits in Chemistry from DSC courses.

Semester -wise Scheme

Semester I

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours /week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0101	Introduction to Atomic Structure, Bonding and Quantitative Analysis	100	Chemistry Major -DSC Chemistry Minor -DSC Chemistry Disci - DSC	4	3-0-2	50	50	100
24-808-0102	Chemistry in Everyday Life	100	Chemistry Minor-DSC	4	4-0-0	50	50	100
24-808-0103	General Chemistry -I	100	MDC	3	3-0-0	50	50	100
Semester Credits for Chemistry Major	21 (AEC: 6, MDC: 3, Major pathway: 4, Minor pathway: 8) Cumulative credits: 21							

L: Lecture, T: Tutorial, P: Practical

Chemistry Major-DSC: Core course for students Majoring in Chemistry.
Chemistry Minor-DSC: Core course for students Minoring in Chemistry.
Chemistry Disci-DSC: Core course for students who choose discipline mention in Chemistry.
Chemistry -MDC: Multidisciplinary elective course offered to students whose Major or Minor pathways are different from Chemistry.
AEC: Ability Enhancement Course (Languages). MDC: Multidisciplinary Course.

Semester II

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours/ week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0201	Introduction to Physical Chemistry and Inorganic Qualitative Analysis	100	Chemistry Major -DSC Chemistry Minor-DSC Chemistry Disci-DSC	4	3-0-2	50	50	100
24-808-0202	Electrochemistry, Solid State and Colloids	100	Chemistry Minor -DSC	4	4-0-0	50	50	100
24-808-0203	General Chemistry II	100	Chemistry MDC	3	3-0-0	50	50	100
Semester Credits for Chemistry Major	21 (AEC: 6, MDC: 3, Major pathway: 4, Minor pathway: 8) Cumulative credits: 42							

Semester III

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours/ week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0301	Introduction to Organic Chemistry and Organic Qualitative Analysis	100	Chemistry Major -DSC, Chemistry Minor-DSC, Chemistry Disci-DSC	4	3-0-2	50	50	100
24-808-0302	Elements of symmetry and Spectroscopy	200	Chemistry Minor-DSC	4	4-0-0	50	50	100
24-808-0303	General Chemistry III	100	Chemistry MDC	3	3-0-0	50	50	100
Semester Credits for Chemistry Major	21 (VAC: 6, MDC: 3, Major pathway: 4, Minor pathway: 8) Cumulative credits: 63							

Semester IV

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours /week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0401	Inorganic Chemistry I	200	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0402	Organic Chemistry I	200	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0403	Physical Chemistry I	200	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0404	Theoretical Chemistry I	200	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-04YY*	SEC -I	200	Chemistry SEC	3	2-0-2	50	50	100
Semester Credits for Chemistry Major	22 (VAC: 3, SEC: 3, Major pathway: 16) Cumulative credits: 85							

* Skill Enhancement Course

Semester V

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours /week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0501	Inorganic Chemistry II	300	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0502	Organic Chemistry II	300	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0503	Physical Chemistry III	300	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0504	Theoretical Chemistry II	300	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0505	Advanced Organic Synthesis and Industrial Chemistry Lab	300	Chemistry Major -DSC	4	0-0-8	100	-	100
24-808-05YY	SEC II	300	Chemistry -SEC	3	1-0-4/ 2-0-2	50	50	100
Semester Credits for Chemistry Major		23 (SEC: 3, Major pathway: 20) Cumulative credits: 108						

Semester VI

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours/ week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0601	Inorganic Chemistry III	300	Chemistry Major - DSC	4	4-0-0	50	50	100
24-808-0602	Organic Chemistry III	300	Chemistry Major - DSC	4	4-0-0	50	50	100
24-808-0603	Physical Chemistry III	300	Chemistry Major - DSC	4	4-0-0	50	50	100
24-808-0604	Advanced Physical and Inorganic Chemistry Lab	300	Chemistry Major - DSC	4	0-0-8	100	-	100
24-808-06XX	Elective I*	300	Chemistry Major - DSE Chemistry Minor - DSE	4	4-0-0	50	50	100
24-808-06YY	SEC III	300	Chemistry SEC Chemistry Minor – DSE	3	1-0-4	50	50	100
Semester Credits for Chemistry Major		23 (SEC: 3, Major pathway: 20) Cumulative credits: 131						

* Elective courses for Chemistry Major/Minor

Internship

Students have to complete an internship of 2 credits (60 Hours of work) before the beginning of Semester VII. Cumulative Credits: 133

Exit with 3-year UG Degree OR continue to the 4th year.

Semester VII

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours /week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0701	Inorganic Chemistry IV	400	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0702	Organic Chemistry IV	400	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0703	Theoretical Chemistry III	400	Chemistry Major -DSC	4	3-0-2	50	50	100
24-808-0704	Scientific Writing and Presentation	500	Chemistry Major -DSC	2	0-0-4	100	-	100
24-808-07XX	Elective II	400	Chemistry Major -DSC Chemistry Minor– DSE	4	4-0-0	50	50	100
24-808-07XX	Elective III	400	Chemistry Major -DSE Chemistry Minor-DSE	4	4-0-0	50	50	100
Semester Credits for Chemistry Major	22 (Major/ minor pathway: 22) Cumulative credits: 155							

Semester VIII

For Honours with Research

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours /week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0801	Research Proposal Writing	500	Chemistry Major -DSC	2	1-0-2	100	-	100
24-808-0802	Project	500	Chemistry Major -DSC	12	0-0-24	200	100	300
24-808-0803	Advanced Analytical and Instrumentation Techniques	500	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0804	MOOC	400	Chemistry Major -DSE	4			100	100
Semester Credits for Chemistry Major	22 (Major and Minor pathway: 22) Cumulative credits: 177							

For Honours

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours /week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0801	Research Proposal Writing	500	Chemistry Major -DSC	2	1-0-2	100	-	100
24-808-0802	Mini Project	500	Chemistry Major -DSC	4	0-0-8	50	50	100
24-808-0803	Advanced Analytical and Instrumentation Techniques I	500	Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0804	MOOC	400	Chemistry Major -DSE	4				100
24-808-08XX	Elective IV	400/500	Chemistry Major -DSE Chemistry Minor -DSE	4	4-0-0	50	50	100
24-808-08XX	Elective V	400/500	Chemistry Major -DSE Chemistry Minor -DSE	4	4-0-0	50	50	100
Semester Credits for Chemistry Major	22 (Major and pathway: 22) Cumulative credits: 177							

Exit with 4-year UG Degree (177 Credits) OR continue to the 5th year.

Semester IX

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours /week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-0901	Advanced Analytical and Instrumentation Techniques II		Chemistry Major -DSC	4	4-0-0	50	50	100
24-808-0902	Advanced Instrumentation Lab	600	Chemistry Major -DSC	4	0-0-8	100	-	100
24-808-0903	Mini Project	600	Chemistry Major -DSC	4	0-0-8	50	50	100
24-808-09XX	Elective VI	500	Chemistry Major -DSE	4	4-0-0	50	50	100
24-808-09XX	Elective VII	500	Chemistry Major -DSE	4	4-0-0	50	50	100
Semester Credits for Chemistry Major	20 (Major pathway: 20) Cumulative credits: 197							

Semester X

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	Credits	Hours/ week L-T-P	Marks distribution		
						CA	ESE	Total
24-808-1001	Major Project	600	Chemistry Major -DSC	20	0-0-40	600		600
24-808-1002	MOOC **	500	Chemistry Major -DSE	4			100	100
Semester Credits for Chemistry Major	22 (Major pathway: 24) Cumulative credits: 221							

**Department Council will approve a set of courses the students can take. Students can take one MOOC course with 4 credits or 2 courses with 2 credits depending on the availability to complete the credit requirements. The students can enroll for the courses during IXth semester and the credits will be added to the Xth semester grades. If a students fails a course, he/she may take same or another course with the approval of the Department council.

LIST OF SKILL ENHANCEMENT COURSES

SEC I

24-808-0405 Industrial Chemistry

SEC II

24-808-0506 Advanced Techniques in Organic Synthesis: Theory and Practice

24-808-0507 Spectro Analytical Chemistry

SEC III

24-808-0605 Visualization and Computing

LIST OF ELECTIVES

ELECTIVE I

24-808-0606

24-808-0607

ELECTIVE II, III

24-808-0705 Polymer Chemistry

24-808-0706 Supramolecular Chemistry

ELECTIVE IV,V

24-808-0805 Electronic Structure From Molecules to Solids

24-808-0806 Advanced Organic Chemistry I

24-808-0807 Material Chemistry

24-808-0808 Transition Metals: Chemistry and applications in Organic Synthesis

ELECTIVE VI, VII

24-808-0904	Computational Materials Chemistry
24-808-0905	Advanced Organic Chemistry II

Syllabus

24-808-0101 Introduction to Atomic structure, Bonding and Quantitative Analysis (4 Credits)

LTP 3-0-2 Level: 100

Pre-requisite: None

CO	CO Statement	CL
CO1	Appreciate the evolution of quantum mechanics and correlate the concepts to modern atomic structure.	Apply
CO2	Analyse the structure and bonding in simple molecules by applying the concepts of MOT.	Analyse
CO3	Correlate the physical and chemical properties of elements based on their periodic classification.	Apply
CO4	Perform a statistical analysis of experimental data	Apply
CO5	Quantitative estimation through titrimetric analysis	Analyse

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	1	1	0
CO2	2	2	1	1	1	0
CO3	2	2	3	2	1	0
CO4	2	2	2	1	1	0
CO5	1	1	1	1	2	1

Module I (11 hrs)

Atomic structure I - Blackbody emission and temperature, Photoelectric effect, Double slit experiment, Line spectrum of elements, Rutherford's experiment, Bohr's atomic model, Failure of Classical mechanics, Evolution of quantum mechanics - Heisenberg's uncertainty principle and its significance, wave particle duality, de Broglie equation.

Module II (11 hrs)

Atomic Structure -II - Quantum atomic model, hydrogen atomic orbitals and quantum numbers, atomic orbital equations (no derivation required), Sign of wave functions. Radial and angular wave functions. Radial and angular distribution curves. Shapes of s, p, d and f orbitals. Contour boundary and probability diagrams.

Module III (12 hrs)

Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Lande equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Solvation energy, Covalent bond, Valence Bond theory, Resonance and resonance energy, Molecular orbital theory. bonding, non- bonding, antibonding molecular orbitals (concept only) elementary pictorial approach of homo- and hetero-diatomic molecules H_2, B_2, C_2, O_2, N_2, CO, NO and CO_2, H_2O etc.

Module IV (11 hrs)

Periodic Properties: Atomic weights, Development of periodic law, The modern periodic table, Basis of periodic classification, orbital types and periodic table, Commonality in electronic configurations, Atomic sizes, ionization energy, Electronegativity, Electron Affinity, Polarizability and polarizing power, Relative orbital energies and overlap, Trends associated with properties – Physical and chemical, Anomalies in periodic properties.

Module V (Lab 30 hrs)

Titrimetric analysis and calculations: Different types of titrations - neutralization, redox (permanganometry, dichrometry, iodometry, iodimetry), complexometric (EDTA titrations) and precipitation titrations.

Principle of all types of titrations, titration curves, indicators. Significant figures, Accuracy, Precision, Error, Types of errors- Determinate and Indeterminate errors, Distribution of random errors, Mathematical Expression for error- Absolute and Relative error, Methods to reduce error, Statistical tools for expressing precision- Standard deviation, Relative standard deviation, Variance, Comparison of results- Student's t test, f test, Criteria for rejecting a value-Q test, Confidence interval

Recommended Books

1. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4^{th} Ed., W.H. Freeman & Company, 2006.
2. Housecroft, C. and Sharpe, G., Inorganic Chemistry, 4^{th} Edn., Pearson, 2012.
3. Atkins, P.W. and Paula, J. Physical Chemistry, 8^{th} Edn., Oxford Press, 2006
4. Lee, J.D. Concise Inorganic Chemistry, 5^{th} Edn., John Wiley & Sons, 1999.
5. Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of Inorganic Chemistry, 3rd Ed., Oxford, 1994.
6. Day, M.C. and Selbin,J. Theoretical Inorganic Chemistry, 2^{nd} Edn., ACS Publications, 2002.
7. Skoog, West, Holler, Crouch, Fundamentals of Analytical Chemistry, Wiley, 9^{th} Edn.
8. Fifield, F. W., Kealey, D., Principles and Practice of Analytical Chemistry, Academic Press, 5^{th} Edn.
9. Robinson, J. W., Skelly Frame, E. M., Frame, G. M., II, Undergraduate Instrumental Analysis, Prentice Hall, 2009
10. Vogel’s Textbook of Quantitative Chemical Analysis, 6^{th} Edn, ELBS, 1998.

24-808-0102 Chemistry in Everyday Life (4 Credits)

L-T-P 4-0-0 **Level:100**
Pre-requisite: None

CO	CO Statement	CL
CO1	Understand the importance and the role of chemistry in everyday life	Understand
CO2	Learn about chemicals that lay the foundation for life	Understand
CO3	Understand the type of chemicals used in household activities, cosmetics and medicine	Apply
CO4	Apply knowledge of chemistry to improve quality of life	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	2	0	1	1
CO2	3	1	2	1	2	0
CO3	2	2	3	2	1	1
CO4	2	2	2	1	1	1

Module I (10 hrs)

Molecules of Life - Cellular and chemical foundations of life, water unique properties, Carbohydrates and their sources, monosaccharides and disaccharides, examples, Lipids, Amino acids, Nucleic acids, Vitamins, Nutrients, Enzymes, Hemoglobin, structure and function, effect of CO, chlorophyll.

Module II (15 hrs)

Chemistry for food: chemicals used in kitchen, Butter and edible oils, composition, importance, properties, saturated and unsaturated fatty acids, hydrogenated oils, milk and dairy products, chemistry of cooking, chemical and physical changes during cooking, microwave cooking, nutrients and their stability during cooking, food preservation, colouring and flavouring agents, Beverages, food adulteration, food poisoning.

Module III (10 hrs)

Chemistry for cleaning: Soaps, chemical composition, preparation, cleaning action, synthetic detergents, bleaching, other house hold cleaning agents, tooth paste, mouth wash, sanitizers, shaving cream, shampoo disinfectants and antiseptics

Module IV (10 hrs)

Chemistry for cosmetics: Basic concepts-composition and classification, Skin chemistry, deodorants, antiperspirants, perfumes fragrances, effect of sunlight on skin, vitamin D, skin burns, sun screens, skin and hair care products, talcum powder, lipstick, moisturizers, colouring and bleaching agents, cosmetic formulations, baby care products

Module V (15 hrs)

Chemistry for medicines: Contribution of chemistry to human health and historical developments in medicine, Classification and nomenclature, Structure and function of: Analgesics – aspirin, paracetamol, Anthelmintic drug: mebendazole, Antiallergic drug: Chlorpheniramine maleate, Antibiotics: Penicillin V, Chloromycetin, Streptomycin. Sulfa drugs, Anti-inflammatory agent: Oxypheno-butazone, Antimalarials: Primazuine phosphate & Chloroquine, tranquilizer, antidepressants, antihistamines, drugs for chemotherapy, Generic and brand names

Recommended Text Books:

1. Chemistry in Daily Life by KIRPAL SINGH, PHI Learning Pvt Ltd
2. Chemistry Connection, The Chemical Basis of Everyday Phenomena, Karukstis, Kerry K. and Van Hecke, Gerald R, Harcourt/Academic Press (2003)
3. Chemistry in the Marketplace (5th ed.) Harcourt Brace (1998)
4. Introduction to Industrial Chemistry, B. K. Sharma: Goel Publishing, Meerut (1998)
5. Medicinal Chemistry by Asthoush Kar
6. Drugs and Pharmaceutical Sciences Series, Marcel Dekker, Vol.II, INC, New York.
7. Foods – Facts and Principles. N. Shakuntala Many and S. Swamy, 4th ed. New Age International (1998).

24-808-0103 General Chemistry -1 (3 Credits)

L-T-P 3-0-0 Level: 100

Pre-requisite: None

CO	CO Statement	CL
CO1	Appreciate the evolution of quantum mechanics and correlate the concepts to modern atomic structure.	Apply
CO2	Analyse the structure and bonding in simple molecules by applying the concepts of MOT.	Analyse
CO3	Correlate the physical and chemical properties of elements based on their periodic classification.	Apply
CO4	Perform a statistical analysis of experimental data	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	1	1	0
CO2	2	2	1	1	1	0
CO3	2	2	3	2	1	0
CO4	2	2	2	1	1	0

Module I (11 hrs)

Atomic structure I - Blackbody emission and temperature, Photoelectric effect, Double slit experiment, Line spectrum of elements, Rutherford's experiment, Bohr's atomic model, Failure of Classical mechanics, Evolution of quantum mechanics - Heisenberg's uncertainty principle and its significance, wave particle duality, de Broglie equation.

Module II (11 hrs)

Atomic Structure -II - Quantum atomic model, hydrogen atomic orbitals and quantum numbers, atomic orbital equations (no derivation required), Sign of wave functions. Radial and angular wave functions. Radial and angular distribution curves. Shapes of s, p, d and f orbitals. Contour boundary and probability diagrams.

Module III (12 hrs)

Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Lande equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Solvation energy, Covalent bond, Valence Bond theory, Resonance and resonance energy, Molecular orbital theory. bonding, non- bonding, antibonding molecular orbitals (concept only) elementary pictorial approach of homo- and hetero-diatomic molecules H_2, B_2, C_2, O_2, N_2, CO, NO and CO_2, H_2O etc.

Module IV (11 hrs)

Periodic Properties: Atomic weights, Development of periodic law, The modern periodic table, Basis of periodic classification, orbital types and periodic table, Commonality in electronic configurations, Atomic sizes, ionization energy, Electronegativity, Electron Affinity, Polarizability and polarizing power, Relative orbital energies and overlap, Trends associated with properties – Physical and chemical, Anomalies in periodic properties.

Recommended Books

1. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4^{th} Ed., W.H. Freeman & Company, 2006.
2. Housecroft, C. and Sharpe, G., Inorganic Chemistry, 4^{th} Edn., Pearson, 2012.
3. Atkins, P.W. and Paula, J. Physical Chemistry, 8^{th} Edn., Oxford Press, 2006
4. Lee, J.D. Concise Inorganic Chemistry, 5^{th} Edn., John Wiley & Sons, 1999.
5. Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of Inorganic Chemistry, 3rd Ed., Oxford, 1994.
6. Day, M.C. and Selbin,J. Theoretical Inorganic Chemistry, 2^{nd} Edn., ACS Publications, 2002.

24-808-0201 Introduction to Physical Chemistry and Inorganic Qualitative Analysis (4 Credits)

L-T-P 3-0-2 Level: 100

Pre-requisite: None

CO	CO Statement	CL
CO1	Differentiate the properties of real gases from those of a perfect gas and predict the properties	Apply
CO2	Predict changes in thermodynamic parameters during a process and predict the spontaneity.	Analyse
CO3	Apply the concepts of chemical kinetics and photochemistry to calculate rate/ rate constants/quantum yield of different types of reactions	Apply
CO4	Understand the basic surface phenomena and extended application to adsorption.	Apply
CO5	Understand the basic principles of qualitative inorganic analysis and to identify the cations and anions in a given solution	Analyse

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	1	1	0
CO2	3	3	2	1	1	0
CO3	3	2	2	1	1	0
CO4	3	2	2	1	1	0
CO5	3	3	3	1	1	0

Module I (11 hrs)

Gaseous State: Kinetic Theory of gases, Maxwell Boltzmann distribution of molecular velocities (Qualitative approach), Different types of velocities, Gas Laws, Ideal gas equation, Real gases- Deviation from ideal behavior- Compressibility factor, Van der Waals equation, Virial equation, PV isotherms, Continuity of states, Law of corresponding states, Critical phenomena and critical constants. Transport properties.

Module II (12 hrs)

Thermodynamics: State functions, Reversible and irreversible processes, Isothermal and adiabatic processes, First, second and third laws of thermodynamics, Concepts of work, heat, Internal energy, enthalpy, Heat capacity, entropy, Gibbs energy, Helmholtz energy, Work done in isothermal and adiabatic reversible and irreversible processes, Entropy and free energy as criteria for spontaneity and equilibrium, Unattainability of absolute zero. Standard states. Entropy and free energy changes during isothermal and adiabatic processes, Changes in entropy and free energy with Temperature and pressure, Gibbs Helmholtz equation, Maxwells relations,
Joule Thomson effect- Inversion temperature, Application of J.T effect - Liquefaction of gases.

Module III (12 hrs)

Chemical Kinetics: Rate laws, Order and molecularity, Zero, first, second and third order reactions-

Integration of rate equations, Half-life period, Arrhenius equation. Theories of Reaction rate- Collision Theory, Transition state theory (elementary concepts), Unimolecular reactions- Lindemann mechanism. Complex Reactions -Consecutive, Parallel and Opposing reactions (elementary concepts), Steady state approximation. Chain reactions, Branched chain reactions (basic concepts)
Photochemistry: Photochemical laws, Beer-Lambert Law, Quantum yield, Photophysical and photochemical processes- Jablonski Diagram, Fluorescence, Phosphorescence-, Chemiluminescence, Bioluminescence, Photosensitisation.

Module IV (9 hrs)

Surfaces and Interfaces: Surface free energy and Surface tension, Contact angles and Wetting, Surface films. capillarity, vapour pressure of droplets. Kelvin equation. pressure difference across curved surface -Laplace equation, Surface wetting- hydrophilicity and hydrophobicity.
Adsorption: Physical and chemical adsorption, adsorption isotherms- Langmuir (kinetic derivation), Freundlich and BET (No derivation) isotherms, Determination of surface area using Langmuir and BET isotherms, Catalysis- Homogeneous and heterogeneous, Enzyme catalysis.
Acid Base concepts: Theories of acids and bases- Arrhenius Theory, Bronsted-Lowry definition, pH, PKa , PKb, Lux Flood Definition, Solvent system definition, Lewis Definition, Usanovich Definition, Generalised concepts: Ionic product of water, Common ion effect, Solubility product, Acid strength, Degree of hydrolysis of salts, Buffer solutions, Mechanism of buffer action, Henderson equation.

Module V (Lab 30 hrs)

Systematic qualitative analysis of mixtures containing two acid and two basic radicals from the list given below by semi micro method
Pb^{2+}, Cu^{2+}, Bi^{2+}, Cd^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mg^{2+}, NH_4^{+},
CO_3^{2-}, SO_4^{2-}, NO_3^{-}, F^-, Cl^-, $C_2O_4^{2-}$, CH_3COO^-, PO_4^{3-}

Recommended Books

1. P.W Atkins, Julio De Paula, Physical Chemistry, Oxford University Press, 10th/11th edn, 2017/2018.
2. Ira.N.Levine, Physical Chemistry, Tata Mc Graw Hill, 6th edn (Indian) 2011.
3. R.A.Alberty & R.J.Silbey, Physical Chemistry, Wiley Publishers, 4th edn, 2004.
4. T. Engel and P. Reid, Physical Chemistry, Pearson, 3rd Edn, 2013.
5. K J Laidler, J.H Meiser, Physical Chemistry, 4th edn 2003.
6. K. J. Laidler, Chemical-Kinetics, Paperback Edn., 2018.
7. M. R. Wright, An Introduction to Chemical Kinetics, Wiley, 2004.

24-808-0202 ELECTROCHEMISTRY, SOLID STATE AND COLLOIDS (4 Credits)
L-T-P 4-0-0 Level: 100
Pre-requisite: None

CO	CO Statement	CL
CO1	Describe the theories of ionic conductance and apply the concepts to calculate conductance of a given system	Apply
CO2	Describe the mechanism of electronic conductance at charged interfaces.	Apply
CO3	Describe the regular arrangement of atoms in crystals and the symmetry of their arrangement	Analyse
CO4	Explain the properties of solids and correlate their mechanical, electrical, optical, and magnetic properties with their constituent atoms and molecules.	Analyse
CO5	Describe various types of colloids, their stability and properties	Analyse

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	1	3	2	1
CO2	3	3	1	3	2	1
CO3	3	3	1	3	3	2
CO4	3	3	1	3	3	2
CO5	3	3	1	3	3	2

Module I (12 hours)

Introduction- Ionics, Electrodics, Electrochemical Cells, Electrodes, Electrolytes, Half Reactions, Electrochemical Work, Equilibrium electrochemistry-Half- reactions and electrodes, Types of cells, Types of electrodes- Standard hydrogen electrode, Calomel electrode, Quinhydrone electrode. Ion – Solvent, Ion – Ion Interactions, Ionic and Electronic Conductance, Conductance Measurement, Equivalent Conductance, Kohlrausch's Law, Ostwalds dilution law, Ionic Mobility, Walden's rule, abnormal conductance, Conductometeric titrations.

Module II (12 hours)

Transport Number- Factors Influencing, measurement- Hittorf's and moving boundary methods. Debye-Huckel Theory, Ionic Atmosphere, time of Relaxation, Mechanism of Electrolytic Conductance, Debye Huckel Onsager equation for strong electrolytes. Electrode – Ion interface, liquid junction potential, Double Layer, Overvoltage (Elementary idea)
The electromotive force, Standard potentials, Applications of standard potentials, Determination of solubility product and activity coefficient, pH determination, Potentiometric titrations, Redox indicators principle. Activity and Activity Coefficient of Electrolytes. Corrosion of metals- different forms of corrosion and prevention. Electrochemical Theory of corrosion – methods of prevention. Fuel Cell, Batteries (Elementary idea)

Module III (12 hours)

Crystal structures and symmetry, Crystallographic point groups, space group, unit cells, Miller indices, Seven crystal systems and Bravais lattices, Simple, body centered and face centered systems, Packing in solids- packing diagrams, close packing,- hcp and ccp structures, XRD, Braggs equation – derivation, Powder and rotating crystal technique. Identification of cubic crystals based on interplanar ratio

Module IV (14 hours)

Ionic solids with formula MX (CsCl, NaCl, Zinc Blende and Wurtzite Structures), MX2 (Fluorite and Antfluorite Structures, Cadmium Halides, CaF2, Rutile, Anti-rutile, betacristobalite), other crystal systems (Bismuth tri-iodide, Corundum, Rhenium Trioxide etc.), Mixed oxides (Spinel, Perovskite, Ilmenite). The properties of solids**,** Mechanical properties Electrical properties, Impact on nanoscience: Nanowires, Optical properties, Magnetic properties.

Point Defects in crystals- stoichiometric and non-stoichiometric defects, Line defect, surface defects, Liquid Crystals- Classification and application

Module V (10 hours)

Colloids: Lyophilic and Lyophobic colloids, Preparation of colloids, Kinetic, optical and electrical properties, Electrical double layer Models for double layer: Helmholtz, Gouy- Chapman and Stern models, Zeta potential. Stability of colloids, Protective colloids- Gold number, Flocculation, Hardy Schulze rule, Surfactants, micelles, Donnan membrane equilibrium, Dorn effect, Sedimentation potential and streaming potential, Emulsions, Gels, Sols.

Recommended Books:

1. J. Bockris and A.K.N. Reddy, Modern Electrochemistry, 2nd Edn., Wiley, New York, 1998
2. R. Crow, Principles and Applications of Electrochemistry, , 4th edn, 1994.
3. S. Glasstone, An Introduction to Electrochemistry, Paperback edn., 2007
4. L.V. Azaroff, Introduction to Solids, McGraw Hill, 1960.
5. A. R. West, Solid State Chemistry, Wiley Student (Indian) Ed., (2014)
6. A.K. Galwey, Chemistry of Solids, Chapman and Hall, London, 1967. 35
7. Lesley Smart and Elaine Moore, Solid State Chemistry, Chapman and Hall, 1995
8. H. V. Keer, Principles of the Solid State Wiley Eastern Ltd, New Delhi, 1993.
9. C. N. R. Rao and J. Gopalakrishnan, New Directions in Solid State Chemistry. 2nd edn, Cambridge Uty Press, 1997.
10. P.W. Atkins, Julio De Paula, Physical Chemistry, Oxford University Press, 10th/11th edn, 2017/2018

24-808-0203 General Chemistry II (3 Credits)

L-T-P 3-0-0 Level: 100
Pre-requisite: None

CO	CO Statement	CL
CO1	Differentiate the properties of real gases from those of a perfect gas and predict the properties	Apply
CO2	Predict changes in thermodynamic parameters during a process and predict the spontaneity.	Analyse
CO3	Apply the concepts of chemical kinetics and photochemistry to calculate rate/ rate constants/quantum yield of different types of reactions	Apply
CO4	Understand the basic surface phenomena and extended application to adsorption.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	1	1	0
CO2	3	3	2	1	1	0
CO3	3	2	2	1	1	0
CO4	3	2	2	1	1	0

Module I (11 hrs)
Gaseous State: Kinetic Theory of gases, Maxwell Boltzmann distribution of molecular velocities (Qualitative approach), Different types of velocities, Gas Laws, Ideal gas equation, Real gases- Deviation from ideal behavior- Compressibility factor, Van der Waals equation, Virial equation, PV isotherms, Continuity of states, Law of corresponding states, Critical phenomena and critical constants. Transport properties.

Module II (12 hrs)
Thermodynamics: State functions, Reversible and irreversible processes, Isothermal and adiabatic processes, First, second and third laws of thermodynamics, Concepts of work, heat, Internal energy, enthalpy, Heat capacity, entropy, Gibbs energy, Helmholtz energy, Work done in isothermal and adiabatic reversible and irreversible processes, Entropy and free energy as criteria for spontaneity and equilibrium, Unattainability of absolute zero. Standard states. Entropy and free energy changes during isothermal and adiabatic processes, Changes in entropy and free energy with Temperature and pressure, Gibbs Helmholtz equation, Maxwells relations,
Joule Thomson effect- Inversion temperature, Application of J.T effect - Liquefaction of gases.

Module III (12 hrs)
Chemical Kinetics: Rate laws, Order and molecularity, Zero, first, second and third order reactions- Integration of rate equations, Half-life period, Arrhenius equation. Theories of Reaction rate- Collision Theory, Transition state theory (elementary concepts), Unimolecular reactions- Lindemann mechanism. Complex Reactions -Consecutive, Parallel and Opposing reactions (elementary concepts),

Steady state approximation. Chain reactions, Branched chain reactions (basic concepts)
Photochemistry: Photochemical laws, Beer-Lambert Law, Quantum yield, Photophysical and photochemical processes- Jablonski Diagram, Fluorescence, Phosphorescence-, Chemiluminescence, Bioluminescence, Photosensitisation.

Module V (9 hrs)
Surfaces and Interfaces: Surface free energy and Surface tension, Contact angles and Wetting, Surface films. capillarity, vapour pressure of droplets. Kelvin equation. pressure difference across curved surface -Laplace equation, Surface wetting- hydrophilicity and hydrophobicity.
Adsorption: Physical and chemical adsorption, adsorption isotherms- Langmuir (kinetic derivation), Freundlich and BET (No derivation) isotherms, Determination of surface area using Langmuir and BET isotherms, Catalysis- Homogeneous and heterogeneous, Enzyme catalysis.
Acid Base concepts: Theories of acids and bases- Arrhenius Theory, Bronsted-Lowry definition, pH, PKa , PKb, Lux Flood Definition, Solvent system definition, Lewis Definition, Usanovich Definition,
Generalised concepts: Ionic product of water, Common ion effect, Solubility product, Acid strength, Degree of hydrolysis of salts, Buffer solutions, Mechanism of buffer action, Henderson equation.

Recommended Books

1. P.W Atkins, Julio De Paula, Physical Chemistry, Oxford University Press, $10^{th}/11^{th}$ edn, 2017/2018.
2. Ira.N.Levine, Physical Chemistry, Tata Mc Graw Hill, 6^{th} edn (Indian) 2011.
3. R.A.Alberty & R.J.Silbey, Physical Chemistry, Wiley Publishers, 4^{th} edn, 2004.
4. T. Engel and P. Reid, Physical Chemistry, Pearson, 3^{rd} Edn, 2013.
5. K J Laidler, J.H Meiser, Physical Chemistry, 4^{th} edn 2003.
6. K. J. Laidler, Chemical-Kinetics, Paperback Edn., 2018.
7. M. R. Wright, An Introduction to Chemical Kinetics, Wiley, 2004.

24-808-0301 Introduction to Organic Chemistry and Organic Qualitative Analysis (4 Credits)

L-T-P 3-0-2 Level: 100
Pre-requisite: None

CO	CO Statement	CL
CO1	Assign the nomenclature of simple organic molecules following IUPAC rules and identify various functional groups in organic chemistry.	Apply
CO2	Apply the concepts of isomerism and analyse the conformation and configuration of organic molecules.	Apply
CO3	Describe the different types of organic reactions.	Understand
CO4	Understand the different chemical bonding in organic molecules and reactive intermediates.	Understand
CO5	Understand the nature of biomolecules and develop an insight into the importance of organic chemistry in life.	Understand

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	1	1	1	1
CO2	2	3	1	1	1	1
CO3	2	3	3	2	1	1
CO4	2	2	2	1	1	1
CO5	1	2	1	1	2	1

Module I (10 hrs)
Localized and delocalized chemical bonding, the concept of aromaticity, writing proper Lewis structures, hybridization, reactive intermediates (carbynes, carbenes, carbocation, carbanion, radicals, arynes, nitrenes), Geometry of organic molecules.. "Symbolism" in Organic Chemistry.

Module II (30 hrs)
Nomenclature and functional groups in organic molecules: Rules of IUPAC system of nomenclature, naming of common organic compounds. Introduction to organic functional groups- alcohols, ethers, halides, amines, nitro compounds.
Organic Qualitative Analysis Lab:Identification of simple organic compounds. Preparation of derivatives.

Module III (10 hrs)
Stereochemistry: Configuration and conformation- Concept of configuration, classification of stereoisomers, optical isomerism, chirality, wedge formula, Fischer projection, Newman projection, perspective formula. Relative and absolute configurations, sequence rules, D & L, R & S systems of nomenclature. Enantiomers, meso form, diastereoisomers, epimers, anomers. Geometrical Isomerism: E-Z notation. Conformational analysis: Strain in molecules, acyclic molecules, cyclohexane, substituted cyclohexanes- A values.

Module IV (10 hrs)

Basics of reaction mechanism: Classification and an overview of organic reactions. Electron pushing diagrams. Basics of reaction coordinate diagrams, intermediates, transition states, exothermic and endothermic reactions, activation energy, rates of reactions and rate-determining step. Aliphatic Nucleophilic substitutions - SN1, SN2, substitutions on aromatic carbon, Addition reactions - polar and nonpolar addition - addition of Bromine and hydrogen halides to double bonds - Markownikoff's rule and peroxide effect., Elimination - E1, E2, E1CB, pyrolytic elimination.

Module V (15 hrs)

Introduction to carbohydrates: General introduction to carbohydrates, ring-chain tautomerism, glycosidic linkage, classification, monosaccharides, disaccharides, oligosaccharides, polysaccharides, reducing and nonreducing sugars, structure of aldohexoses, fructose and ribose, "sugar-like" artificial sweeteners, basic introduction to amino acids, proteins and nucleic acids.

Recommended Text Books

1. J. G. Smith, Organic Chemistry, 3rd edn., 2011.
2. Clayden J., Greeves, N. Warren, S., Organic Chemistry, 2nd edn. Oxford University Press, 2001.
3. Bruice, P.Y. Organic Chemistry, 7th edn., Prentice Hall Inc., 2013.
4. March, J., Smith, D., March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 7th edn., Wiley, 2013.
5. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th edn., Springer, 2008.
6. J. McMurry, Organic Chemistry, 5th edn., Brooks/Cole, 2000.
7. P. Sykes, Guidebook to Mechanism in Organic Chemistry, 6th edn., Prentice Hall, 1986.
8. Pavia, D.L. Lampman, G.M. Kriz, G.S. and Engel, R.G. Introduction to Organic Laboratory Techniques: A small scale Approach, 2nd Ed., 2007.
9. Dey, B.B. Sitaraman, M.V. and Govindachari, T.V. Laboratory Manual of Organic Chemistry, 3rd Ed., Viswanathan, 1957.
10. Furniss, B.S. Hannaford, A.J. Smith, P.WG. Tatchell, A.R. Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Longman, 1989

24-808-0302 Elements of Symmetry and Spectroscopy (4 Credits)

L-T-P 4-0-0 Level: 100

Pre-requisite: None

CO	CO Statement	CL
CO1	Analyze the symmetry of any given molecule and assign the point group	Analyse
CO2	Explain the principles of rotational, vibrational, Raman, electronic, fluorescence and NMR spectroscopic techniques	Understand
CO3	Predict the applications and uses of the spectroscopic techniques	Analyse

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	1	3	2	1
CO2	3	3	1	3	2	1
CO3	3	3	1	3	3	2

Module I (10 hrs.)

Symmetry as a universal theme. Different symmetry classes and symmetry operations (discussion with suitable examples). Applications of symmetry to a) Polar molecules b) chiral molecules. Symmetry properties of orbitals (basic concepts); concept of point groups, identification of molecular point groups in some simple molecules.

Module II (8 hrs.)

Spectroscopy and its importance in chemistry. Link between spectroscopy and quantum chemistry. Electromagnetic radiation and its interaction with matter. origin of linewidths in molecular spectra, Transition dipole moment and Fermi's Golden Rule, Einsteins Coefficients, Lasers and Masers; Types of spectroscopy. Difference between atomic and molecular spectra. Separation of molecular energies into translational, rotational, vibrational and electronic components. Born-Oppenheimer approximation, Postulates of quantum mechanics, quantum mechanical operators.

Module III (16 hrs.)

Rotational Motion: Schrödinger equation of a rigid rotator and brief discussion of its results (solution not required). Quantization of rotational energy levels. Microwave (pure rotational) spectra of diatomic molecules. Selection rules. Structural information derived from rotational spectroscopy. determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.
Vibrational Motion: Schrödinger equation of a linear harmonic oscillator and brief discussion of its results (solution not required). concept of zero-point energy. Quantization of vibrational energy levels. Selection rules, IR spectra of diatomic molecules. Structural information derived from vibrational spectra. Vibrations of polyatomic molecules. Group frequencies. Effect of hydrogen bonding (inter- and intramolecular) and substitution on vibrational frequencies.

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.

Module IV (12 hrs.)
Electronic Spectroscopy: Electronic excited states. Free Electron model, its application to electronic spectra of polyenes. Franck-Condon principle, electronic transitions, Beer Lambert's Law, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyenes using free electron model. Colour and constitution, chromophores, auxochromes, bathochromic and hypsochromic shifts.

Module V (14 hrs.)
NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift and factors influencing it; Spin–Spin coupling and coupling constant; Anisotropic effects, Interpretation of NMR spectra of simple compounds. Carbon-13 NMR, introduction to polarization transfer and NOE, 2D NMR, MRI, Solid state NMR
Principle of fluorescence spectroscopy, Quenching of fluorescence, Mechanisms of quenching

Recommended Books:

1. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, 4^{th} Ed. Tata McGraw-Hill: New Delhi, 2006.

2. W.Kemp, Organic Spectroscopy, 3^{rd} Ed., Palgrave, 1991.

3. G. M. Barrow, Physical Chemistry, 6^{th} Ed., McGraw-Hill College, 1996.

4. P.W. Atkins and J.Paula, Physical Chemistry, 8^{th} Ed., Oxford Press, 2006.

5 .I. N. Levine, Physical Chemistry, 6^{th} Ed., McGraw-Hill Education, 2008.

6. F. A. Cotton, Chemical Applications of Group Theory, 3^{rd} Ed., Wiley Interscience, New York, 2008.

7. M. S. Gopinathan and V. Ramkrishnan, Group Theory in Chemistry, 2^{nd} Ed., Vishal Publishing Co., 2013.

8. H. Gunther, NMR Spectroscopy, 2nd ed., John Wiley, 2005.

24-808-0303 General Chemistry III (3 Credits)

L-T-P 3-0-0 Level: 100
Pre-requisite: None

CO	CO Statement	CL
CO1	Assign the nomenclature of simple organic molecules following IUPAC rules	Apply
CO2	Apply the concepts of isomerism and analyse the conformation and configuration of organic molecules.	Apply
CO3	Describe the different types of organic reactions.	Understand
CO4	Understand the different chemical bonding in organic molecules and reactive intermediates.	Understand
CO5	Understand the nature of biomolecules and develop an insight into the importance of organic chemistry in life.	Understand

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	1	1	1	1
CO2	2	3	1	1	1	1
CO3	2	3	3	2	1	1
CO4	2	2	2	1	1	1
CO5	1	2	1	1	2	1

Module I (10 hrs)
Localized and delocalized chemical bonding, the concept of aromaticity, writing proper Lewis structures, hybridization, reactive intermediates (carbynes, carbenes, carbocation, carbanion, radicals, arynes, nitrenes), Geometry of organic molecules.. "Symbolism" in Organic Chemistry.

Module II (7 hrs)
Nomenclature and functional groups in organic molecules: Rules of IUPAC system of nomenclature, naming of common organic compounds. Introduction to organic functional groups- alcohols, ethers, halides, amines, nitro compounds.

Module III (10 hrs)
Stereochemistry: Configuration and conformation- Concept of configuration, classification of stereoisomers, optical isomerism, chirality, wedge formula, Fischer projection, Newman projection, perspective formula. Relative and absolute configurations, sequence rules, D & L, R & S systems of nomenclature. Enantiomers, meso form, diastereoisomers, epimers, anomers. Geometrical Isomerism: E-Z notation. Conformational analysis: Strain in molecules, acyclic molecules, cyclohexane, substituted cyclohexanes- A values.

Module IV (8 hrs)
Basics of reaction mechanism: Classification and an overview of organic reactions. Electron pushing diagrams. Basics of reaction coordinate diagrams, intermediates, transition states, exothermic and

endothermic reactions, activation energy, rates of reactions and rate-determining step. Aliphatic Nucleophilic substitutions - SN1, SN2, substitutions on aromatic carbon, Addition reactions - polar and nonpolar addition - addition of Bromine and hydrogen halides to double bonds - Markownikoff's rule and peroxide effect., Elimination - E1, E2, E1CB, pyrolytic elimination.

Module V (10 hrs)

Introduction to carbohydrates: General introduction to carbohydrates, ring-chain tautomerism, glycosidic linkage, classification, monosaccharides, disaccharides, oligosaccharides, polysaccharides, reducing and nonreducing sugars, structure of aldohexoses, fructose and ribose, "sugar-like" artificial sweeteners, basic introduction to amino acids, proteins and nucleic acids.

Recommended Text Books

1. J. G. Smith, Organic Chemistry, 3rd edn., 2011.
2. Clayden J., Greeves, N. Warren, S., Organic Chemistry, 2nd edn. Oxford University Press, 2001.
3. Bruice, P.Y. Organic Chemistry, 7th edn., Prentice Hall Inc., 2013.
4. March, J., Smith, D., March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 7th edn., Wiley, 2013.
5. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th edn., Springer, 2008.
6. J. McMurry, Organic Chemistry, 5th edn., Brooks/Cole, 2000.
7. P. Sykes, Guidebook to Mechanism in Organic Chemistry, 6th edn., Prentice Hall, 1986.
8. Pavia, D.L. Lampman, G.M. Kriz, G.S. and Engel, R.G. Introduction to Organic Laboratory Techniques: A small scale Approach, 2nd Ed., 2007.
9. Dey, B.B. Sitaraman, M.V. and Govindachari, T.V. Laboratory Manual of Organic Chemistry, 3rd Ed., Viswanathan, 1957.
10. Furniss, B.S. Hannaford, A.J. Smith, P.WG. Tatchell, A.R. Vogel's Textbook of Practical Organic Chemistry, 5 th Ed., Longman, 1989

24-808-0401 INORGANIC CHEMISTRY I: Inorganic Main Group and Nuclear Chemistry (4 Credits)

L-T-P 4-0-0 Level: 200

Pre-requisite: 24-808-0101 or equivalent

CO	CO Statement	CL
CO1	Interpret the types of bonding and structure based on the electronic configuration	Apply
CO2	Explain the reactivity and physicochemical properties based on the type of bonding	Analyse
CO3	Explain the properties of transition metals and lanthanides	Apply
CO4	Compare the structure, bonding and reactivity of the compounds of main group elements	Analyse
CO5	Describe the radioactivity phenomena and its applications	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	2	1	0
CO2	2	2	1	2	1	0
CO3	2	2	1	2	1	0
CO4	2	2	1	2	1	1
CO5	2	2	1	2	1	1

Module I (10 hrs)

s- Block elements- Hydrogen, Hydrogen Bonding, Hydrates, Hydrogen ions, acids and bases,

Group 1 elements - General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Flame colors and spectra, Color of compounds, Alkali metals in liquid ammonia and other solvents, Oxides, hydroxides, hydrides, alkoxides, amido complexes, Ionic salts and M^+ ions in solution, Alkali metal complexes, Organolithium compounds.

Module II (10 hrs)

Group 2 elements – General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Elemental Beryllium, Binary Compounds, Coordination compounds with oxygen and nitrogen ligand, organoberyllium compounds, Compounds of Magnesium, Calcium, Strontium-oxides, halides, hydrides, carbides, ionic salts and complexes, alkoxides. Grignard reagents – preparation and properties.

Module III (14 hrs)

General periodic trends of d and f block elements, Metallic property, Chemistry of variable oxidation states, properties of d configuration - d^0 to d^{10}, Type of compounds. physical and chemical properties of transition elements; Difference between first row and other rows, Double salts and coordination compounds.

Introduction to coordination compounds; coordination numbers and geometries in transition metal complexes; nomenclature; isomerism in transition metal complexes – structural, geometrical and optical isomerism.

Lanthanides and Actinides- Stable oxidation states, lanthanide and actinide contraction, Occurrence and recovery; Separation of Lanthanides; difference between 4f and 5f orbitals, Industrial importance of lanthanides.

Actinides: Comparison with lanthanides and general characteristics

Module IV (14 hrs)
Types of oxides, Chemical properties of Dioxygen, Singlet oxygen, ozone, Peroxo compounds, Superoxide. Nitrogen compounds- Nitrides, Ammonia, Hydrazine, Oxides of Nitrogen, Oxo acids and anions.
Sulphur-Nitrogen compounds: Tetrasulphur tetranitride, disulphur dinitride and polythiazyl. SxNy compounds. S-N cations and anions. Sulphur-phosphorus compounds: Molecular sulphides such as P_4S_3, P_4S_7, P_4S_9 and P_4S_{10}. Phosphorus-nitrogen compounds: Phosphazenes and poly phosphazenes.
Interhalogen compounds, Structure, hybridization and reactivity of ClF_3, ICl_3, IF_5 and IF_7, Compounds of Xe, Kr and Rn.

Module V (12 hrs)
Nuclear radius, Nuclear Forces, Nuclear Spin, Magnetic dipole moment, Elementary Particles, Binding Energy, Nuclear models – Shell model- magic number, periodicity in nuclear properties, Liquid drop model – Fission and Fusion, Nuclear Stability, Exchange theory, n/p ratio, Nuclear Radiations, Nuclear reactions, Types of nuclear reactions, Decay Kinetics, Half-life, Radioactive disintegration series. Fission: Fission products and Fission yield curve, Fission energy, theory of nuclear fission, nuclear reactor, breeder reactor - nuclear reactors in India. Fusion reactions, hydrogen bomb and energy of sun. Radio carbon dating principles.

Recommended Text Books:

1. Mingos, D. M. P., Essential Trends in Inorganic Chemistry, Oxford University Press 1998.
2. Wulfsberg G., Inorganic Chemistry, VIVA, 2002.
3. Greenwood, N. N., Earnshaw, A., Chemistry of the Elements, Maxwell Macmillan International Edition, Pergamon Press, 1989.
4. Cotton, F.A., Wilkinson, G, Advanced Inorganic Chemistry. Wiley-VCH, 1999
5. Huheey, J. E., Keiter, E. A., Kieter, R. L., Medhi, O. K., Inorganic Chemistry Principles Structure and Reactivity, Pearson Education, 4th edition, 2009.
6. Lee, J. D., A New Concise Inorganic Chemistry, ELBS, 1998
7. Miessler, G.L. & Tarr, D. A. Inorganic Chemistry, 5th Ed., Pearson Publication, 2013.
8. Arnikar, H. J., Essentials of Nuclear Chemistry, Wiley Eastern Ltd., New Delhi, 1982.

24-808-0402 Organic Chemistry I: Stereochemistry, Reaction Mechanisms & Rearrangements (4 Credits)

L-T-P 4-0-0 Level: 200

Pre-requisite: 24-808-0301 or equivalent

CO	CO Statement	CL
CO1	Apply the concepts of isomerism and analyze the conformation and configuration of organic molecules.	Apply
CO2	Illustrate the mechanism involved in various reactions.	Apply
CO3	Describe bonding properties in organic molecules.	Understand
CO4	Illustrate the mechanistic pathway of different rearrangement reactions and identify the products	Apply
CO5	Predict the reactivity of an organic compound based on its structure and the reaction conditions	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	1	2	3	1	1
CO2	1	1	2	3	1	1
CO3	1	1	2	3	1	1
CO4	1	1	3	3	1	1
CO5	2	2	3	3	1	1

Module I (12 hrs)

Stereochemistry: Geometrical & Optical isomerism: the origin of chirality, chiral centres and configuration, axes and planes, helicity. Prochiral centres and faces. Topicity relationships, enantiotopic and diastereotopic groups and faces. Symmetry, stereochemistry and time scale. Allenes, cumulenes, biphenyls, and spirans. Compounds containing chiral atoms other than carbon.

Conformational analysis: Acyclic molecules, cyclohexane, substituted cyclohexanes- A values.

Strain, types of strain including B, F, I, Pitzer strain and Baeyer strain. Acyclic sp^3–sp^3, sp^3-sp^2 systems, structure and stability of small, medium, and large rings, cyclohexane, substituted cyclohexanes, cyclohexenes, decalins, and bicyclic systems. Kinetic vs thermodynamic control in ring forming reactions.

Module II (14 hrs)

The study of reactions and the methods of studying reaction mechanisms:– Classification of reactions according to IUPAC conventions. Reaction mechanism: guidelines on Pushing of electrons. Reactive intermediates: Formation, stability and general reactivity. Methods of determining reaction mechanisms (kinetic and non-kinetic methods): The Hammond postulate, reactivity vs selectivity principle, the Curtin-Hammett principle, microscopic reversibility, kinetic *vs* thermodynamic control.

Isotope effects: Primary, secondary and Equilibrium isotope effects, Tunneling effects, solvent isotope effects, and heavy atom Isotope effects.

Linear free energy relationships: Hammett and Taft parameters, Solvent effects (Grunwald-Winstein plots and Schleyer adaptation), nucleophilicity and nucleofugality. Isokinetic and Isoequilibrium temperature, Enthalpy – entropy compensation. Experimental techniques to determine reaction mechanisms: identification of intermediates by trapping and competition experiments, cross-over experiments, isotope scrambling, radical clocks and traps, matrix isolation.

Module III (14 hrs)

Substitutions on Aliphatic carbon: –saturated and unsaturated systems – Mechanism of nucleophilic substitution – S_N2, S_N1 – ion pairs, SET, Neighbouring group participation – non-classical carbocations, SNi, Tetrahedral mechanism. Electrophilic substitution – SE2, SEi, SE1. Free radical substitution. Reactivity – Effect of substrate structure, nature of reagents, solvents and stereochemistry on the outcome of these reactions. Ambident nucleophiles and substrates. Typical reactions involving substitution.

Substitutions on aromatic carbon: Mechanism of electrophilic, nucleophilic and free radical substitutions – orientation and reactivity. Typical reactions involving aromatic substitution.

Module IV (10 hrs)

Additions and eliminations:

Mechanisms of polar addition – electrophilic, nucleophilic and free radical addition. Nonpolar additions (excluding pericyclic reactions) - Reactivity and orientation.

Eliminations - E2, E1 and E1CB mechanisms, reactivity and orientation. Pyrolytic syn eliminations, α - eliminations, elimination *vs* substitution. Typical reactions involving addition and elimination.

Module V (10 hrs)

Rearrangements: Wagner-Meerwein, Pinacol, Demyanov, dienone-phenol, Favorskii, Wolff, Hofmann, Curtius, Lossen, Schmidt, Beckmann, benzidine, and Hofmann-Loffler, Fries, Baeyer-Villiger rearrangements. Fritsch-Buttenberg-Wiechell rearrangement, Corey-Fuchs reaction, Wittig rearrangement.

Recommended Text Books

1. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
2. March, J., Smith, D., March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 7th ed., Wiley, 2013.
3. Bruice, P.Y. Organic Chemistry, 7th ed., Prentice Hall Inc., 2013.
4. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
5. J. McMurry, Organic Chemistry, 5th ed., Brooks/Cole, 2000.
6. P. Sykes, Guidebook to Mechanism in Organic Chemistry, 6th ed., Prentice Hall, 1986.
7. E. L. Eliel and S. H. Wilen, Stereochemistry in Organic Compounds, John Wiley, 1994.
8. P. S. Kalsi, Stereochemistry, Conformation and Mechanism, 10th ed., New Age Publications, 2019.
9. E. V. Anslyn, D. A. Dougherty, Modern Physical Organic Chemistry. University Science Books, 2006.

24-808-0403 Physical Chemistry I: Equilibrium and Statistical and Irreversible Thermodynamics (4 Credits)

L-T-P 4-0-0 Level: 200

Pre-requisite: 24-808-0201 or equivalent

CO	CO Statement	CL
CO1	Predict the dependence of physical and chemical equilibrium on pressure, temperature and concentration.	Apply
CO2	Apply the concept of chemical potential in physical and chemical processes.	Apply
CO3	Understand the thermodynamics of phase transitions and interpret the phase diagram of a given system	Analyse
CO4	Apply the principles of statistical thermodynamics to ideal gases, solids and metals.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	2	1	1	0
CO2	3	3	2	1	1	0
CO3	3	3	3	1	1	0
CO4	3	2	2	1	1	0

Module I (11 hrs)

Recap of the laws of thermodynamics and thermodynamic functions.

Thermochemistry- Enthalpy of physical and chemical changes, Temperature dependence of reaction enthalpies, Hess's law.

Chemical Equilibria: Chemical Equilibria and free energy, Equilibrium Constant, Applications of free energy function to physical and chemical changes- Le Chateliers Principle. Effect of temperature and pressure on the chemical equilibrium- van't Hoff reaction isotherm and isochore.

Module II (11 hrs)

Thermodynamics of Mixtures: Partial molar quantities, Chemical potential, Thermodynamics of mixing, Excess function, Chemical potential of liquids, Gibbs Duhem Equation and Duhem Margules Equation. Ideal solutions, Deviations from ideality, Concepts of fugacity and activity, Ideal dilute solutions, Henry's and Raoult's laws, Colligative properties, Regular solutions.

Module III (11 hrs)

Physical Transformation of substances: Phase stability and transitions, phase equilibria of pure substances, Clausius Clapeyron equation, Solid-liquid, liquid-vapor and solid-vapor equilibria, phase rule, phase diagrams of one-component systems, Ehrenfest Classification of Phase transitions.

Phase Equilibria of Binary and ternary Systems: Vapor pressure-composition diagrams, Temperature-composition diagrams, Liquid-liquid systems – Completely miscible, Partially miscible and Immiscible, Azeotropes and Azeotropic distillation, Steam distillation. Solid-Liquid systems, Solid-vapour systems.

Three-component systems.

Module IV (15 hrs)

Thermodynamic probability, microstate and macrostate, entropy and probability, most probable distribution, residual entropy and its calculation. Ensembles, Maxwell - Boltzman statistics.
Quantum statistics: Bose - Einstein statistics, Fermi - Dirac statistics, Comparison of Maxwell - Boltzman, Bose- Einstein and Fermi - Dirac Statistics, Dilute Systems.
Partition function and its relation to thermodynamic properties: Translational, rotational and Vibrational partition function. Molecular partition function for delocalized systems, calculation of equilibrium constant using partition functions. Heat capacity of gases and solids. Anomalous heat capacity of hydrogen.

Module V (12 hrs)

Linear Non-equilibrium thermodynamics: General theory, Local entropy production, balance equation for concentration. Energy conservation in open systems. Entropy balance equation. Forces and Fluxes, Steady state and local equilibrium conditions. Linear phenomenological laws. Phenomenological coefficient, Systems with heat, matter and electrical transport, Onsager Reciprocal relation, Application to Diffusion -Thermal diffusion, Thermal Osmosis and electrokinetic effects, Soret Coefficient, Seebeck effect.

Recommended Books

1. P.W Atkins, Julio De Paula, Physical Chemistry, Oxford University Press, $10^{th}/11^{th}$ edn, 2017/2018.
2. Ira.N.Levine, Physical Chemistry, Tata Mc Graw Hill, 6^{th} edn (Indian) 2011.
3. R.A.Alberty & R.J.Silbey, Physical Chemistry, Wiley Publishers, 4^{th} edn, 2004.
4. D.A McQuarrie, J.D Simon, Molecular Thermodynamics, Viva Student Edn. 2010.
5. L. K. Nash, Elements of Chemical Thermodynamics, Addison Wesley, 2^{nd} Edn, 2013.
6. F.W Sears, Introductions to Thermodynamics, Kinetic Theory of Gases and Statistical Mechanics, Addision Wesley Pub. Cambridge, 1998.
7. F.C. Andrews, Equilibrium to Statistical Mechanics, John Wiley, New York, 2002.
8. L.K. Nash, Statistical Thermodynamics, Addison Wesley, New York, 1999.
9. D. A. McQuarrie, Physical Chemistry- A Molecular Approach, South Asian Edn., 2008.
10. D. A. McQuarrie, Statistical Thermodynamics, South Asian Edn., 2008.
11. M. Dole, Introduction to Statistical Thermodynamics, Prentice Hall, London, 1997.

24-808-0404 Theoretical Chemistry I: Quantum Mechanics (4 Credits)

L-T-P 4-0-0 Level: 200

Pre-requisite: None

CO	CO Statement After the completion of the course the student will be able to	CL
CO1	Describe and justify the importance of Quantum Mechanics	Analyse
CO2	Understand and apply various postulates in deriving property operators and Schrodinger equation	Apply
CO3	Apply the postulates of quantum mechanics to simple systems of chemical interest, such as the particle-in-a-box, harmonic oscillator, rigid rotor and Hydrogen atom	Analyse
CO4	Interpret the solutions and appreciate the quantization concept	Analyse

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	0	2	1	0
CO2	3	1	0	2	1	0
CO3	3	1	0	3	1	0
CO4	3	2	0	3	2	1

Module I (15 hrs)

Basics: Evolution of quantum mechanics, Heisenberg's matrix mechanics- commutator relationships, position representation, coordinate- Cartesian, cylindrical and spherical polar and their interconversion, Complex number and their representation in various coordinate systems. Operators, Algebra of operators, Linear and Hermitian operators, Eigenvalue equation, Significance, well-behaved functions, Time dependent Schrodinger equation, conservative and non-conservative systems

Module II (10 hrs)

Solving the Schrodinger equation-Particle in a box: Quantum mechanical postulates, construction of various operators – kinetic energy, angular momentum. Translational motion- free particle, particle in one, two and three-dimensional box (rectangular and cubical), separation of variables, concept of degeneracy, introduction to quantum mechanical tunneling.

Module III (12 hrs)

Solving the Schrodinger equation-Simple Harmonic oscillator: Vibrational motion, 1-D Harmonic oscillator, Method of power series, Hermite equation and Hermite Polynomials, Recursion formula, wave function and energy. Transition moment integral, selection rules, Extension of the results to 3D-SHO.

Module IV (08 hrs)

Solving the Schrodinger equation-Planar Rigid Rotor: Rigid rotator, Conversion of laplacian opertor into spherical polar coordinates, Particle on a ring, phi equation, Angular momentum operator L^2 and Lz, quantization, polar plots. Solving the Schrodinger equation-Non-planar RR: Theta equation and solutions Lagendre equation and Lagendre polynomials, Restriction of m_l values, Spherical harmonics,Angular momentum operator L^2 and Lz, Space quantization, polar plots of spherical harmonics.

Module V (15 hrs)

Solving the Schrodinger equation- iv) Hydrogen atom: Separation into three equations and solutions, Theta and phi equations and solutions, Spherical harmonics, Radial equations and solutions, Laguerre equation and Laguerre polynomials. Solutions of wave functions and energies, quantum numbers and their importance, Radial wave function and radial distribution functions, angular wave function, Shapes of s, p, d and f atomic orbitals.

Recommended Text Books:

1. Atkins, P.W. and Paula, J. Physical Chemistry, 8th Ed., Oxford Press, 2006.
2. Szabo, A.; Ostlund, N. S. "Modern Quantum Chemistry: Introduction to Advanced Electronic Structure theory", Dover Publications, 1996.
3. Levine, I. N. "Quantum Chemistry", 7th Ed., Pearson Education Inc., 2014.
4. McQuarrie, D. A., "Quantum Chemistry", 2ndEd.,University Science Books, 2008.
5. Pillar, F. L. "Elementary Quantum Chemistry", 2nd Ed., Dover Publication, 2001.
6. Chandra, A. K., "Introduction to Quantum Mechanics", 4th Ed, Tata McGraw-Hill, New Delhi, 2003.
7. Prasad, R. K., "Quantum Chemistry", 4thEd, New Age International, 2009.

24-808-0405 SEC – 1 Industrial Chemistry (3 Credits)

L-T-P 2-0-2 Level: 200

Pre-requisite: None

CO	CO Statement	CL
CO1	Prepare and analyze industrially important chemical products	Create
CO2	Prepare the treatment methods for conversion of natural resources to value added chemicals	Create

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	1	2	2	3	3
CO2	2	1	2	2	2	3

Module 1 (15 hours)

Fats and oils general introduction, chemical composition of fats and oils, quality parameters, sources and classification, value added products from vegetable oils. Cleaning products general introduction, Chemistry of cleaning action, classification of cleaning products, Soap and Detergents, chemical composition, principles of preparation, different methods, builders and additives, quality parameters Margarine- Importance, chemical composition, preparation methods, principles of emulsification Biodiesel: energy scenario, consumption pattern, fossil fuel depletion and environmental issues, Alternate solutions, transesterification; FT process, catalysts; biodiesel purification, fuel properties

Module 2 (8 hours)

Water purification: Concept of Pure Water, Water Contamination, Water Purification Methods, Water quality parameters

Module 3 (7 hours)

General introduction to essential oils and natural flavours, natural sources, extraction techniques and principles

Module 4 (10 hours)

Practice: Preparation, characterization and quality analysis of value added products from vegetable oils (soap, margarine, vanaspati

Module 5: (10 hours)

Practice: Purification of contaminated water, estimation of quality parameters, pH, conductivity, Total Dissolved Solids, hardness, turbidity, Dissolved oxygen, COD, chloride

Module 6: (10 hours)

Practice: Extraction and characterization of essential oils and flavours from natural sources

Recommended Text Books:

1. Krishna Chattopadhyay and Manas Mandal ANALYTICAL CHEMISTRY SKILL ENHANCEMENT COURSE, CBSCBS Publishers & Distributors, 2022
2. J. N. Gurtu, and A. Gurtu Advanced Physical Chemistry Experiments, 6th Ed., Pragati Prakashan,

2014.
3. J. B. Yadav, Advanced Practical Physical Chemistry, 36^{th} Ed., Krishna Prakashan, 2016

24-808-0501 INORGANIC CHEMISTRY-II: Polyhedral Boranes, Coordination & Bioinorganic Chemistry (4 Credits)

L-T-P 4-0-0 Level: 300

Pre-requisite: 24-808-0401 or equivalent

CO	CO Statement	CL
CO1	Describe and explain the structure, bonding and magnetism of metal complexes using CFT.	Analyse
CO2	Describe the metal-ligand interactions in terms of sigma and pi bonding and covalency using LFT and MO theory	Evaluate
CO3	Understand the importance of metal ions in living systems	Analyse
CO4	Predict the stability and topology of different polyhedral boranes and related compounds.	Analyse

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	3	2	1
CO2	3	2	1	3	2	1
CO3	3	2	1	2	2	1
CO4	3	2	1	3	2	1

Module I (10 hrs)

Werner's theory, Effective atomic number, Bonding in coordination compounds.

Valence bond description and its limitations. valence bond theory (inner and outer orbital complexes). Crystal Field Theory (CFT). d-orbital splitting in octahedral and tetrahedral geometries, measurement of 10 Dq (Δo), crystal field stabilization energy, CFSE in weak and strong fields, effect of pairing energy, factors affecting the crystal-field parameters.

Crystal field splitting of square planar, trigonal bipyramidal, trigonal planar and linear geometries.

Module II (12 hrs)

Application of crystal filed theory, colour and spectral behaviours. magnetism of first-row transition metal complexes, lattice energies, ionic radii, site preferences in spinels. Spectrochemical series, Demerits of CFT.

Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, Jahn – Teller effect in octahedral and tetrahedral complexes, square planar geometry. Stabilization of unusually low and high oxidation states of metals.

Module III (12 hrs)

Molecular Orbital Theory: construction of molecular orbital diagrams (using group theory-qualitative idea only), qualitative MO diagrams for octahedral, tetrahedral and square planar complexes, effect of π-bonding, experimental evidence for π-bonding, spectrochemical series.
Ligand field theory, Effect of π-donor and π-acceptor ligands in LFSE, back bonding.

Module IV (12 hrs)

Metal ions in biological systems - Biochemistry of iron – Haemoglobin and myoglobin - O_2 and CO_2 transportation (Elementary idea of structure and oxygen binding), Structure and mechanism of action of sodium potassium pump - Biochemistry of Ca, Zn and Co – Toxicity of metal ions (Pb, Hg and As).
Anticancer drugs: *Cis*-platin, oxaliplatin and carboplatin– Structure and significance.
Non-Heme Iron Proteins: Iron storage and transfer – ferritin, transferrin; electron transfer (Iron-sulfur protein) – rubredoxin, ferredoxin; O_2 transport – hemerythrin
Copper proteins and Enzymes–Hemocyanin, superoxide dismutase, ceruloplasmin, cytochrome C oxidase; Zinc and Cobalt enzymes carbonic anhydrase, carboxypeptidase, interchangeability of zinc and cobalt enzymes; Vitamin B12; Photosynthesis and N_2 fixation.

Module V (14 hrs)

Electronic structure and allotropes of boron, boron halides, boron heterocycles, borazine Structure and bonding in polyhedral boranes and carboranes, styx notation; electron count in polyhedral boranes; Wade's rule; topological approach to boron hydride structure. Importance of icosahedral framework of boron atoms in boron chemistry. Closo, nido and arachno structures. Synthesis of polyhedral boranes;
Electron counting in polycondensed polyhedral boranes, mno rule. Carboranes, metallocarboranes.

Recommended Text Books:

1. Purcell, K.F & Kotz, J.C. Inorganic Chemistry, 2nd Ed., W.B. Saunders Co, 1991.
2. Huheey, J. E., Keiter, E. A. and Keiter, R. L. Inorganic Chemistry, Principle and structure and reactivity, 4th Ed., Harper Collins College Publishers, New York, 1993.
3. Miessler, G.L. & Tarr, D. A. Inorganic Chemistry, 5th Ed., Pearson Publication, 2013.
4. C. E. Housecroft, A. G. Sharpe, Inorganic Chemistry, 5th ed., Pearson, 2018.
5. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley- Interscience, 1999.
6. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4th Ed., W.H. Freeman & Company, 2006.
7. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry 2nd Ed., University Science Books, 1994.
8. Greenwood, N.N. & Earnshaw A., Chemistry of the Elements, 2nd., Ed. Butterworth-Heinemann,1997.
9. Sharpe, A.G. Inorganic Chemistry, 4th Indian Reprint, Pearson Education, 2005.
10. Douglas, B. E.; McDaniel, D.H. and Alexander, J.J. Concepts and Models in Inorganic Chemistry 3rd Ed., John Wiley and Sons, NY, 1994.
11. W. L. Jolly, Modern Inorganic Chemistry, McGraw-Hill International, 2nd Edition, New York, 1991.

24-808-0502 Organic Chemistry II: Analytical and Spectroscopic Techniques

(4 Credits)

L-T-P 4-0-0 Level: 300

Pre-requiste: None

CO	CO Statement	CL
CO1	Apply the principles of separation, purification and chromatographic techniques in organic synthesis.	Apply
CO2	Identify structures of simple organic compounds based on the data from UV-Vis, IR, Mass Spectrometry, ^{1}H NMR and ^{13}C NMR spectroscopy.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	3	3	3	1	1
CO2	2	3	3	3	1	1

Module I (12 hrs)

Separation and Purification Techniques: Recrystallization, use of drying agents, sublimation. General principles of distillation, fractional distillation, steam distillation, and distillation under reduced pressure. Solvent extraction. Chromatographic Techniques: Chromatography - Principle of differential migration. Classification of chromatographic methods. Basic principles and uses of Thin layer chromatography (TLC), Paper chromatography (PC), Rf value, Column chromatography, Gas chromatography (GC), High-performance Liquid chromatography (HPLC), and Size exclusion chromatography.

Module II (12 hrs)

UV-visible Spectroscopy: Types of electronic transitions, Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; Effect of structure on absorption characteristics, Application of Woodward Rules for calculation of λ_{max} for the following systems: α,β-unsaturated aldehydes and ketones, λ_{max} for polyenes, aromatic aldehydes, ketones, esters.

IR spectroscopy: Fundamental and non-fundamental molecular vibrations; IR absorption positions of O and N containing functional groups; Effect of H-bonding, concentration, temperature, conjugation, resonance and ring size on IR absorptions; Fingerprint region and its significance; application in functional group analysis. Fourier transform IR, group frequencies, fundamental frequencies and overtones, combination tones, Fermi Resonance. Basic introduction to Raman spectroscopy.

Module III (14 hrs)

NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift and factors influencing it; Spin–Spin coupling and coupling constant; Anisotropic effects in alkene, alkyne, aldehydes and aromatics, Interpretation of NMR spectra of simple compounds. Proton decoupled Carbon-13 NMR, introduction to polarization transfer and NOE.

Module IV (11 hrs)

Mass spectrometry – Introduction. EI ionization. Fragmentation modes and determination of molecular mass by MS.
Soft ionization techniques, ion separation and analysis, and hyphenated techniques.
HRMS and molecular formula.

Module V (11 hrs)
Problems based on the combined application of various spectroscopic techniques.

Recommended Books

1. Brian S. Furniss, Antony J. Hannaford, Peter W. G Smith, Austin R.Tatchell, Vogel's Textbook of Practical Organic Chemistry, 5th Edition, Longman Scientific and Technical, 1989.
2. D.L.Pavia, G.M. Lampman, G.S.Kriz, Introduction to Spectroscopy, A Guide for Students of Organic Chemistry, 3rd ed., Thomson. 2004.
3. R. M. Silverstein, G.C. Bassler, T. C. Morril, Spectroscopic identification of organic compounds, John Wiley, 1991.
4. D. H. Williams, I. Fleming, Spectroscopic Methods in Organic Chemistry, Tata McGraw Hill. 1988.
5. W. Kemp, Organic Spectroscopy, 2nd ed., ELBS-Macmillan, 1987.
6. Spectral databases (RIO DB of AIST, for example).
7. C. N. Banwell, Fundamentals of Molecular Spectroscopy, 4th ed., Tata McGraw Hill, 1996.

24-808-0503 Physical Chemistry II: Chemical Kinetics, Surface Chemistry and Catalysis (4 Credits)

L-T-P 4-0-0 Level: 300

Pre-requisite: 24-808-0201 or equivalent

CO	CO Statement	CL
CO1	Interpret the basic reaction dynamics and kinetics of various reactions and obtain the rate constants for reactions in gaseous state and solutions.	Analyse
CO2	Calculate the thermodynamic parameters from kinetic data	Apply
CO3	Apply the basic principles of acid-base and enzyme catalysis to any given kinetic data.	Apply
CO4	Explain the fundamentals of photochemical and photophysical processes and energy/electron transfer.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	3	1	1	2
CO2	3	3	2	1	1	2
CO3	3	2	3	1	1	2
CO4	3	2	2	1	1	2

Module I (12 hrs)

Complex Reactions: Parallel, Consecutive and Opposing reactions, Steady state Approximation, Kinetics of chain reactions - Photochemical reactions H_2-Cl_2 and H_2-Br_2 reaction, Organic decomposition reactions-Rice Herzfield mechanism (acetaldehyde and ethane), Branched Chain Reactions, Explosions-

Somenoff Hinshelwood mechanism (H_2-O_2 reaction), Termolecular reactions.

Module II (12 hrs)

Molecular reaction dynamics: Reactive encounters, Theories of reaction rates-Collision Theory recap), Activated Complex Theory- Potential energy surface, Erying equation, Comparative evaluation of collision and transition state theory, Thermodynamic treatment of reaction rates. Theory of unimolecular reactions- Lindemann Mechanism, Modifications to Lindemann mechanism- Hinshelwood, RRK and

RRKM model. Termolecular reactions. Molecular beam methods, Stripping and rebound mechanism.

Module III (12 hrs)

Reactions in Solutions: Cage effect, Transition state theory for reactions in solutions, Effect of ionic strength, dielectric constant and Internal pressure. Primary and secondary salt effect. Solute-solvent interactions. Ion dipole and dipole-dipole reactions. Diffusion controlled reactions. Isotope effects: Equilibrium isotope effects. Primary and Secondary kinetic isotope effects

Module IV (12 hrs)

Surface Chemistry: Gibbs adsorption isotherm. BET isotherm (derivation).

Catalysis: Catalysis and Inhibition, Homogeneous and heterogeneous Catalysis – Transition state theory, General mechanism. General Mechanism of homogeneous catalysis- Arrhenius and vant Hoff intermediates, Acid base catalysis- specific and general acid catalysis, Enzyme catalysis- Michaelis- Menten Mechanism, Competitive and non competitive inhibition. Kinetics of Surface catalysis: Unimolecular and bimolecular Surface reactions. Kinetics of adsorption- Langmuir Hinshelwood mechanism and Rideal-Eley mechanism. Autocatalysis- Oscillatory reactions- Lotka- Volterra, Oregonator, Brussellator.

Module V (12 hrs)

Photochemistry: Photochemistry and photophysics- Applications, Excited state reactivity and life time, Excimers and Exciplex, Energy and electron transfer -Elementary idea, Quenching- Static and Dynamic, Stern Volmer equation, Applications- Photocatalysis and artificial photosynthesis (Elementary principles).

Recommended Text Books

1. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York.
2. K. J. Laidler, Chemical-Kinetics, McGraw Hill, New York.
3. M. R. Wright, An Introduction to Chemical Kinetics, Wiley, 2004.
4. Richard Masel, Chemical kinetics and Catalysis, Wiley Interscience.
5. P. W. Atkins, Physical Chemistry 8th Edn., Wiley, New York.
6. Christian Reichardt, Solvents and Solvent effects in Organic Chemistry, Wiley VCH 2003.
7. A. W. Adamson, The Physical Chemistry of Surfaces, 2nd Edn., Wiley. New York

24-808-0504 Theoretical Chemistry II: Spectroscopy (4 Credits)
L-T-P 4-0-0 Level: 300
Pre-requisite: None

CO	CO Statement	CL
CO1	Explain the factors affecting the intensity and broadening of lines in spectra and methods to enhance the sensitivity.	Understand
CO2	Explain the principles of rotational, vibrational, Raman, electronic, ,fluorescence, NMR and ESR.	Understand
CO3	Calculate the energy required for a particular type of energy transition and determine the parameters involved.	Apply
CO4	Apply various theoretical aspects to various spectroscopic techniques for prediction of different spectroscopic observations.	Analyse
CO5	Identify various d-d transitions and interpret the electronic spectra of any giventransition metal complex.	Apply
CO6	Interpret the ESR and Mossbauer spectra of given transition metal complex.	Evaluate

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	1	3	2	1
CO2	3	3	1	3	2	1
CO3	3	3	1	3	3	2
CO4	3	3	1	3	3	2
CO5	3	3	1	3	3	2
CO6	3	3	1	3	3	2

Module I (8 hours)

Population of energy levels. Induced quantum transitions. Integrated absorption coefficient. Einstein's coefficients of absorption. Basis of selection rules, transition moment integral. Beer's Law. Induced absorption and emission of radiation by molecules, Factors affecting the intensity and width of spectral lines, Methods to reduce line broadening.

Module II (14 hours)

Rotational and vibrational energies of diatomic molecules. Linear molecules, Symmetric top and asymmetric top molecules. Rotation spectra: Diatomic and polyatomic molecules, Selection rule. Vibration spectra of diatomic molecules, Morse potential of real molecules, overtones, combination and hot bands, Fermi resonance, rotational character of vibration spectra. Coupling of rotation and vibration. Parallel and perpendicular bands.

Vibration spectra of polyatomic molecules, Normal modes of vibrations of polyatomic molecules. Raman Spectroscopy. Rotational Raman spectra. Vibrational Raman spectra, Resonance Raman, mutual exclusion principle. Selection rules and applications to IR and Raman spectra, Surface enhanced Raman spectroscopy.
Applications of Group theory for molecular vibration, symmetry of group vibrations. Selection rules and applications to IR and Raman spectra.

Module III (14 hours)
Electronic energy states of molecules. Selection rules for electronic transitions, Vibrational structure of electronic bands. Electronic transitions and absorption bands. Electronic spectra of diatomic and polyatomic molecules, its relation to electronic arrangement and symmetry of molecules. Different types of electronic transitions, Electronic spectra of conjugated systems.
Principle of fluorescence spectroscopy, Quenching of fluorescence, Mechanisms of quenching Magnetic resonance spectroscopy: Theory of nuclear magnetic resonance, Chemical shifts, Factors affecting chemical shifts, First order and second order spectra, relaxation effects. Fourier Transformation in NMR, Measurement of relaxation time, Spin echo, NOE, 2D NMR, NQR Spectroscopy. MRI, Solid state NMR.
Principle of electron spin resonance.

Module IV (12 hours)
Microstates, Atomic term symbols Free ion terms for dn configuration, Splitting of terms in octahedral and tetrahedral octahedral fields, Correlation diagram for d2 configuration in octahedral geometry, d-d transitions, Selection rules for electronic transitions.
Orgel diagram – splitting for d1, d9, high spin d4, d6, splittings for high spin d2, d3, d8 and d7. Calculation of Dq, B and β
Tanabe Sugano diagrams – splittings for low spin dn systems
Electronic Spectral interpretation of some coordination compounds
Consequence of Jahn Teller effect on the electronic spectra of coordination compounds
Charge transfer spectra, Electronic spectra of lanthanide and actinide complexes

Module V (12 hours)
Electronic paramagnetic resonance spectroscopy: Electronic Zeeman effect, Zeeman Hamiltonian and EPR transition energy. EPR spectrometers, presentation of spectra. The effects of electron Zeeman, nuclear Zeeman and electron nuclear hyperfine terms in the Hamiltonian on the energy of the hydrogen atom. Second order effect. Hyperfine splittings in isotropic systems, spin polarization mechanism and McConnell's relations Anisotropy in g-value, EPR of triplet states, zero field splitting, Kramer's rule, survey of EPR spectra of first row transition metal ion complexes.

Mossbauer spectra of Fe (II) and Fe (III) cyanides.

Recommended Text Books:

1. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed., Pearson, 2014.
2. F. A. Cotton, G. Wilkinson, C. A, Murillo, M. Bochmann Advanced Inorganic Chemistry, 6th ed., Wiley-Interscience: New York, 1999.
3. J.E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of structure and

Reactivity, 4th ed., Harper Collin College Publishers, 1993.

4. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3rd ed., ELBS, 1999.
5. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd ed., John Wiley and Sons, 1994.
6. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd ed., BH, 1997.
7. R. S.Drago, Physical Methods for Chemists, 2nd ed., Saunders College Publishing, 1992.
8. C. E. Housecroft, A. G. Sharpe, Inorganic Chemistry, 5th ed., Pearson, 2018.
9. W. L. Jolly, Modern Inorganic Chemistry, 2nd ed., McGraw-Hill, New York, 1991.
10. Solid state chemistry: an introduction, Lesley Smart and Elaine Moore, 4th ed. Taylor and Francis, 2012.
11. Earnshaw, A. Introduction to Magnetochemistry, Academic Press, 1968.
12. Carlin, R.L. Magnetochemistry, Spinger-Verlag, Berlin, 1986.
13. P. W. Atkins, Physical Chemistry 8th ed., W. H. Freeman, New York, 2006.
14. R. A. Alberty, Physical Chemistry 8th ed., Wiley, New York, 1994.
15. G. M. Barrow, Introduction to Molecular Spectroscopy, McGraw Hill, New York, 1962
16. C. N. Banwell, Fundamentals of Molecular Spectroscopy, 4th ed., Tata McGraw Hill, 1996.
17. H. Gunther, NMR Spectroscopy, 2nd ed., John Wiley, 2005.

24-808-0505 Advanced Organic Synthesis And Industrial Chemistry Lab (4 Credits)
L-T-P 0-0-8 Level: 300
Pre-requisite: 24-808-0301 or equivalent

	Course Outcome	CL
CO1	Prepare organic compounds through one step synthesis and purify and recrystallize the product.	Analyse
CO2	Plan and perform synthetic procedures, chromatographic separation and purification of organic compounds.	Understand
CO3	Use software to Draw the structures and schemes of organic molecules and reactions.	Apply
CO4	Separate organic compounds from the organic binary mixture and identify the functional group(s) present.	Analysis
CO5	Use Chemical Abstracts, Scopus, Organic Synthesis collective volumes on web etc. to search, analyse and collect chemical information.	Apply
CO6	Prepare and analyze industrially important chemical products	Create
CO7	Prepare the treatment methods for conversion of natural resources to value added chemicals	Create

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	2	3	3	3	2	3
CO6	2	3	3	2	3	3
CO7	3	3	3	3	3	3

Module I

One step synthesis of Organic Compounds, General methods of separation and purification of Organic compounds such as 1) Solvent extraction 2) Thin layer chromatography and paper chromatography 3) column chromatography.

Module II

Part I: Separation and identification of the components of organic binary mixtures.

Part II: Preparation of Organic compounds by multistep reactions. Progress of the reactions should be followed by spectroscopic and chromatographic methods. Purification of products and characterisation using UV-Vis, FTIR and NMR.

Part III : Use Chemical Abstracts, Scopus, Organic Synthesis collective volumes on web etc., to search, analyse and collect chemical information.

Module III -V

1. Preparation of soap and detergents

2. Preparation of margarine

3. Preparation and physical property measurement of natural, synthetic rubber, fiber.

4. Extraction of essential oils

5. Extraction of natural flavors

6. Preparation of Biogas

7. Wastewater treatment

8. Preparation and characterization of nanomaterials

9. Preparation of silicon from Rice Husk

10. Galvanization/powder coating

Recommended Textbooks:

1. Pavia, D.L. Lampman, G.M. Kriz, G.S. and Engel, R.G. Introduction to Organic Laboratory Techniques: A small scale Approach, 2nd Ed., 2007.
2. Mann, F.G. Saunders, B.C. Practical Organic Chemistry, 4th Ed., Pearson Education India, 2009.
3. Furniss, B.S. Hannaford, A.J. Smith, P.WG. Tatchell, A.R. Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Longman, 1989.
4. A. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Vogel's Textbook of Practical Organic Chemistry, 5th Ed., John Wiley, 1989.
5. L. W. Harwood, C. J. Moody, Experimental Organic Chemistry-Principles and Practice, Blackwell Science Publications.
6. G. Pass, H. Sutcliffe. Practical Inorganic Chemistry 2nd Ed., Chapman & Hill. 1974.
7. N. Gurtu, and A. Gurtu Advanced Physical Chemistry Experiments, 6th Ed., Pragati Prakashan, 2014.
8. Yadav, J. B., Advanced Practical Physical Chemistry, 36th Ed., Krishna Prakashan, 2016.

24-808-0506 Advanced Techniques in Organic Synthesis: Theory and Practice (3 Credits)

L-T-P 1-0-4 Level: 300

Pre-requisite: 24-808-0301 or equivalent

CO	CO Statement	CL
CO1	Independently organizing and carrying out the most sophisticated and widely used organic transformations in a safe lab setting.	Apply
CO2	Characterize simple to complex molecules using spectroscopic methods.	Analyse

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	3	3	3	1
CO2	3	3	3	3	3	1

Module I (7 hrs)

General methods in organic synthesis: Condensation, substitution, cycloaddition, oxidation, and reduction. Methods for heterocycles and their important reactions.

Module II (8 hrs)

Advanced organic reactions: Multicomponent reactions, organo-catalysed reactions, click reactions. Cross-coupling reactions, metathesis reactions, and application in the synthesis of functional molecules and drugs.

Module III (20 hrs)

Practice : General methods of separation and purification of organic compounds such as 1) Solvent extraction 2) Thin layer chromatography and paper chromatography 3) column chromatography.

Drawing the structures of organic molecules and reaction schemes by Proprietary and open source computer software. Use Chemical Abstracts, Scopus, Scifinder etc., to search, analyse and collect chemical information.

Module IV (20 hrs)

Practice: Hands-on training in conducting reactions under an inert atmosphere and usage of Schlenk line techniques. Drying of solvents like THF, methanol and toluene. Handling of the Glove box. Green strategies such as microwave, sonochemistry, electrochemical and photochemical reactions. Training in cross-coupling reactions and olefin metathesis.

Module V (20 hrs)

Practice: Characterization of synthesized molecules using GC, LCMS, IR, NMR and HPLC techniques. Determination of specific rotation of enantiopure molecules.

Recommended Text Books

1. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
2. A. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Vogel's Textbook of Practical Organic Chemistry, 5th ed., John Wiley, 1989.
3. P. S. Kalsi, Stereochemistry, Conformation and Mechanism, 10th ed., New Age Publications, 2019.
4. T. Tsuji, Transition Metal Reagents and Catalysts: Innovations in Organic Synthesis, John Wiley & Sons, 2000.
5. D. L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Spectroscopy, A Guide for Students of Organic Chemistry, 3rd ed., Thomson. 2004.
6. J. R. Mohrig, D. G. Alberg, G. E. Hofmeister, P. F. Schatz, C. N. Hammond, Laboratory Techniques in Organic Chemistry, 4th ed., W. H. Freeman and Company, 2014.

24-808-0507 Spectroanalytical Chemistry (3 Credits)

L-T-P 2-0-2 Level 300

Pre-requisite: None

CO	CO Statement	CL
CO1	Acquire theoretical and practical knowledge in instrumentation aspects of spectroanalytical devices.	Apply
CO2	Acquire skill to independently operate the instruments.	Apply
CO3	Interpret the data and derive qualitative and quantitative analysis	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	3	3	2	2
CO2	2	3	3	2	2	2
CO3	2	2	3	3	2	1

Module I (8 hrs)

A brief introduction to analytical methods in chemistry, Qualitative analysis and quantitative analysis, applications in day to day life**.** Introduction to various spectro analytical techniques, concept of light matter interaction, Jablonski Diagram and origin of different spectroscopies.

Module II (10 hrs)

Brief theoretical introduction to colourimetry, absorption spectroscopy, fluorescence spectroscopy, vibrational spectroscopy, refractometry, polarimetry, smartphone spectroscopy

Module III (12 hrs)

Detailed Instrumentation aspects of colourimeter, UV-VIS-NIR spectrometer, Fluorimeter, IR spectrometer, Raman spectrometer, refractometer, smartphone spectrometers

Module IV (10 hrs)

Practice: Colurimetry and UV-VIS spectroscopy: hands on training on the instrument, preparation of stock solutions, verification of Beeer-Lambertz law, Estimation of unknown concentration, establish correlation between molecular structure and spectrum, smartphone spectroscopy and comparison with colorimetry and UV-VIS spectroscopy

Module V (12 hrs)

Practice: vibrational spectroscopy: hands on training on the instrument, preparation of samples, IR and Raman spectroscopic characterization of organic and inorganic samples, assignment of peaks to functional groups, spectral processing, data processing, chemometry and machine learning tools., preparation of nanomaterials of surface enhanced Raman spectroscopy, comparative study of Raman and SERS

Module VI (8 hrs)

Practice: Refractometry and Polarimetry: hands on training on the instrument, preparation of stock solutions, estimation of refractive index and optical activity, estimation of unknown concentration, analysis of food samples

Recommended Text Books

1. Krishna Chattopadhyay and Manas Mandal, ANALYTICAL CHEMISTRY SKILL ENHANCEMENT COURSE,
2. Gurtu, J. N., Gurtu, A., Advanced Physical Chemistry Experiments, 6th Ed.,Pragati Prakashan,2014.

24-808-0601 Inorganic Chemistry – III (4 Credits)

L-T-P 4-0-0 Level: 300

Pre-requisite: None

CO	CO Statement	CL
CO1	Analyze the symmetry of any given molecule and assign the point group	Analyse
CO2	Apply the principles of symmetry and group theory in structure, bonding and spectral characteristics of molecules	Apply
CO3	Identify the structure-activity relationship of simple molecules based on their qualitative molecular orbitals.	Apply
CO4	Assess the strength of various acids and bases and their reactivity.	Evaluate
CO5	Explain behavior of different non-aqueous solvent systems towards different reactions.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	3	2	1
CO2	3	2	1	3	2	2
CO3	3	2	1	3	2	1
CO4	3	2	1	3	2	1
CO5	3	2	1	3	2	1

Module I (15 hrs)

Matrix representation of symmetry operations, similarity transformation and classes, Symmetry classification of molecules into point groups (Schoenflies symbol)- Reducible and Irreducible representations - Great Orthogonality theorem and its consequences (statement only, proof not needed), Character tables, Reduction formula, construction of character tables for point groups with order ≤6-, Interpretation of character tables. Wave functions as bases for irreducible representations, Direct product.

Application of symmetry to predict polar and chiral compounds

Module II (15 hrs)

Application of Group theory to Hybridization of atomic orbitals: Construction of hybrid orbitals for AB3(planar), AB4(Td), AB5(D3h) and AB6(Oh) type of molecules.

Application of group theory to Molecular Orbital Theory: LCAO and Huckel approximations. Symmetry adapted linear combinations, Projection operators, Application of projection operators to pi-bonding in ethylene, cyclopropenyl systems, benzene and naphthalene. Application of projection operators to sigma bonding in ethylene and PtCl4 . Molecular orbitals for tetrahedral and octahedral molecules,

Applications of Group theory for molecular vibration, symmetry of group vibrations. Selection rules and applications to IR, Raman and electronic spectra.

Module III (10 hrs)

Qualitative molecular orbital theory, symmetry of molecular orbitals, MOs for homo and heteronuclear diatomic molecules, H_2 to F_2, HF, CO, NO, BeH_2, CO_2, H_2O, BH_3, NH_3, B_2H_6. Importance of frontier molecular orbitals, Shape, energy and reactivity of molecules.

Module IV (10 hrs)

Relative strength of acids, Pauling rules, Lewis concept, Generalized acid-base concept, Measurement of acid base strength, Lewis acid –base interactions, steric and solvation effects, acid–base anomalies, Pearson's HSAB concept, acid-base strength and hardness and softness, Symbiosis, theoretical basis of hardness and softness, electronegativity and hardness.

Module V (10 hrs)

Chemistry in non-aqueous solvents reactions in NH_3, liquid SO_2, solvent character, reactions in SO_2, acetic acid, solvent character, reactions in H_2SO_4 and some other solvents. Molten salts, Green solvent: supercritical CO_2, Ionic liquids and deep eutectic solvents.

Recommended Books

1. F. A. Cotton, Chemical Applications of Group theory, Wiley Eastern, Singapore, 2nd ed., 1992.
2. V. Ramakrishnan, M. S. Gopinathan, Group theory in Chemistry, Vishal Pub. New Delhi, 1996.
3. Alan Vincent, Molecular Symmetry and Group Theory: A Programmed Introduction to Chemical Applications, 2nd ed., Wiley, 2013.
4. Robert L. Carter, Molecular Symmetry and Group Theory, Wiley, 2009.
5. Kieran C. Molloy, Group Theory for Chemists: Fundamental Theory and Applications, 2nd edition, Woodhead publishing, 2010.
6. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed., Pearson, 2014.
7. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of Structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
8. F. A. Cotton, G. Wilkinson, C. A, Murillo, M. Bochmann, Advanced Inorganic Chemistry, 6th ed., Wiley- Interscience: New York, 1999.
9. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3rd ed., ELBS, 1999.
10. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd ed., Wiley, 1994.
11. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd ed., Butterworth-Heinemann, 1997.
12. C.E. Housecroft, A.G. Sharpe, Inorganic Chemistry, 5th ed., Pearson, 2018.

24-808-0602 Organic Chemistry III: Reactions, Reagents, Photochemistry & Pericyclic Reactions (4 Credits)

L-T-P 4-0-0 Level: 300

Pre-requiste: 24-808-0402 or equivalent

CO	CO Statement	CL
CO1	Interpret the differences in reactivity of various reducing, oxidizing agents, organometallic and organo-nonmetallic reagents with mechanistic illustrations.	Apply
CO2	Analyze the reagents and conditions for the synthesis of specific target molecules.	Analyse
CO3	Identify the mechanism and the product in a given reaction under photochemical conditions.	Apply
CO4	Apply the concepts of Frontier orbital theory in the study of pericyclic reactions.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	3	2	1	1
CO2	3	3	3	3	1	1
CO3	3	3	2	2	1	1
CO4	2	3	1	1	1	1

Module I (13 hrs)

Reagents for oxidation and reduction: Chromium reagents, activated DMSO, osmium tetroxide, selenium dioxide, singlet oxygen, peracids, hydrogen peroxide, periodic acid, lead tetraacetate, ozonolysis, Woodward and Prevost hydroxylation, Wacker process, Oppenauer oxidation, Sharpless, Shi and Jacobsen asymmetric epoxidations. Catalytic hydrogenations (heterogeneous-Palladium/Platinum/Rhodium and Nickel, homogeneous-Wilkinson), metal hydride reduction-$LiAlH_4$, DIBAL-H, Red-Al, $NaBH_4$ and $NaCNBH_3$. Selectrides, trialkylsilanes and trialkyl stannane. Birch reduction, hydrazine and diimide reduction. Meerwein-Ponndorf-Verley reaction, Enzymatic reduction using Baker's yeast.

Module II (13 hrs)

Synthetic applications of organometallic and organo-nonmetallic reagents: Hydroboration reactions, Sakurai allylation, Gilman's reagent, Ullmann and Glaser coupling reactions. Suzuki coupling, Sonogashira coupling, Heck reaction, Buchwald–Hartwig coupling, Negishi coupling and Stille coupling. Metathesis processes of electrophilic carbene complexes (first- and second-generation Grubbs catalyst), ROMP, Dötz reaction and methylenation of carbonyls.

Application of reagents such as NBS, DCC, DMAP, DEAD, DDQ. Phase transfer catalysts. Chemistry of Nucleophilic Heterocyclic Carbenes (NHCs), multicomponent reactions such as Ugi reaction, Passerini reaction and Biginelli reaction. Click reaction.

Module III (14 hrs)

Chemistry of carbonyl compounds: Reactivity of carbonyl groups in aldehydes, ketones, carboxylic acids, esters, acyl halides and amides. Substitution at carbonyl carbon, mechanisms of ester

hydrolysis, substitution at α-carbon, aldol and related reactions. Grignard reaction, Reformatsky reaction, Claisen, Darzen, Dieckmann, Knoevenagel and Stobbe condensations. Perkin, Prins, Mannich, Stork-enamine reactions. Conjugate additions, Michael additions and Robinson annulation. Favorskii reaction, Julia olefination, Peterson olefination. Preparation of 1,2-, 1,3-, 1,4- and 1,5-diketones from simple ketones.
Reaction with phosphorous and sulfur ylides

Module IV (8 hrs)
Photochemistry: Unimolecular and bimolecular processes in the excited states, mechanism of important photochemical reactions, Paterno-Buchi reaction, Norrish Type I and Type II fragmentation, di-pi-methane rearrangement, Barton reaction, photochemistry of olefins, arenes, cyclohexadienones; photoreduction and photo-oxygenation.

Module V (12 hrs)
Pericyclic reactions: Study of the principle of conservation of orbital symmetry: Orbital symmetry diagrams for cycloaddition and electrocyclic reactions. Aromatic Transition State Theory and The Generalized Woodward – Hoffmann rule applied to cycloadditions, Electrocyclic reactions, Sigmatropic rearrangements and Chelotropic reactions. Pericyclic Reactions in Organic Synthesis: Stereochemistry and Regiochemistry of Cycloadditions. Substituent and medium effects, Secondary Orbital Interactions in [4+2] cycloadditions, Intramolecular Diels–Alder reactions. Stereochemistry of Electrocyclic Reactions and Sigmatropic rearrangements. Cope rearrangement, Claisen rearrangement and ene-reaction. Pericyclic reactions in Organic synthesis – case studies.

Recommended Books

1. M. B. Smith, Organic Synthesis, 2nd ed., McGraw-Hill, 2000.
2. M. B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 7th ed., Wiley, 2013.
3. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
4. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
5. N. J. Turro, V. Ramamurthy, J. C. Scaiano, Modern Molecular Photochemistry of Organic Molecules, University Science Books, 2010.
6. E. V. Anslyn, D. A. Dougherty, Modern Physical Organic Chemistry. University Science Books, 2006.
7. H. R. Crabtree, The Organometallic Chemistry of the Transition Metals, 6th ed., John Wiley & Sons, 2014.
8. S. D. Burke, R. L. Danheiser, Handbook of Reagents for Organic Synthesis, John Wiley & Sons, 1999.

24-808-0603 Physical Chemistry III: Electrochemistry and Solid State Chemistry (4 Credits)

L-T-P 4-0-0 Level: 300

Pre-requisite: None

CO	CO Statement	CL
CO1	Describe the theories and mechanism of ionic and electronic conductance and apply the concepts.	Apply
CO2	Explain the basic theory of electroanalytical techniques..	Apply
CO3	Understand basic properties and symmetry of solids	Understand

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	3	2	3	2
CO2	3	3	2	2	2	2
CO3	3	3	2	2	1	1

Module I (10 hrs)

Introduction- Electrochemical Cells, Electrodes, Types of electrodes- Standard hydrogen electrode, Calomel electrode, Quinhydrone electrode. Electrolytes, Half Reactions, Electrochemical Work, Electrodics: Equilibrium electrochemistry- Half- reactions and electrodes, Standard Electrode potential, Nernst Equation. EMF and free energy. Types of cells. Electrochemical series. Liquid junction potential. Ion–Solvent, Ion–Ion Interactions, Ionic and Electronic Conductance, Conductance Measurement, Equivalent Conductance, Kohlrausch's Law, Ostwalds dilution law, Ionic Mobility, Walden's rule, abnormal conductance, Transport Number- Factors Influencing, measurement- Hittorf's and moving boundary methods.

Module II (12 hrs)

Electrode–Ion interface, liquid junction potential, Electrical Double Layer, Electrode and Electrolyte polarization. Overpotential. Butler Volmer Equation. Tafel Plot. Mass transfer control, Charge transfer at electrode-electrolyte interface. Double layer. Electrocapillarity. Hydrogen and Oxygen overvoltage. Activity and Activity co-efficients, Debye-Huckel Theory, Limitations. Extension, Bjerrum ion pair formation. Ionic Atmosphere, Relaxation, Mechanism of Electrolytic Conductance, Debye Huckel Onsager equation for strong electrolytes.

Module III (11 hrs)

The electromotive force, Standard potentials, Applications of standard potentials, Determination of solubility product and activity co-efficient, Activity and Activity Coefficient of Electrolytes.

Corrosion of metals- different forms of corrosion and prevention. Electrochemical Theory of corrosion – methods of prevention. Porbaux and Evans diagram. Fuel Cell, Batteries: Basic theory and types (Elementary idea)

Module IV (12 hrs)

Electroanalytical Techniques: pH determination, Redox indicators principle. Conductometric and potentiometric titrations. Cyclic voltammetry, Square wave, and linear sweep voltammetry, Chronoamperometry, Chronopotentiometry, Impedance. Coulometry and Polarography, Spectroelectrochemistry (Basic Principles)

Module V (15 hrs)

Crystal structures and symmetry, Crystallographic point groups, space group, unit cells, Miller indices, Seven crystal systems and Bravais lattices, Simple, body centered and face centered systems, Packing in solids- packing diagrams, close packing,- hcp and ccp structures, XRD, Braggs equation – derivation, Powder and rotating crystal technique. Identification of cubic crystals based on interplanar ratio.

Ionic solids with formula MX (CsCl, NaCl, Zinc Blende and Wurtzite Structures), MX2 (Fluorite and Antfluorite Structures, Cadmium Halides, CaF2, Rutile, Anti-rutile, betacristobalite), other crystal systems (Bismuth tri-iodide, Corundum, Rhenium Trioxide etc.), Mixed oxides (Spinel, Perovskite, Ilmenite). The properties of solids**,** Mechanical properties Electrical properties, Impact on nanoscience: Nanowires, Optical properties, Magnetic properties.

Point Defects in crystals- stoichiometric and non-stoichiometric defects, Line defect, surface defects,

Liquid Crystals- Classification and application.

Recommended Books

1. J. Bockris and A.K.N. Reddy, Modern Electrochemistry, 2nd Edn., Wiley, New York, 1998
2. R. Crow, Principles and Applications of Electrochemistry, Paper back edn, 4th edn, 1994.
3. S. Glasstone, An Introduction to Electrochemistry, Paperback Edn., 2007.
4. Skoog, West, Holler, Crouch, Fundamentals of Analytical Chemistry, Wiley, 9th Edn.
5. L.V. Azaroff, Introduction to Solids, Mc Graw Hill, 1960.
6. A. R. West, Solid State Chemistry, Wiley Student (Indian) Ed., (2014)
7. A.K. Galwey, Chemistry of Solids, Chapman and Hall, London, 1967. 35
8. Lesley Smart and Elaine Moore, Solid State Chemistry, Chapman and Hall, 1995
9. H. V. Keer, Principles of the Solid State Wiley Eastern Ltd, New Delhi, 1993.
10. C. N. R. Rao and J. Gopalakrishnan, New Directions in Solid State Chemistry. 2nd Edn, Cambridge Uty Press, 1997.

24-808-0604 Advanced Physical and Inorganic Chemistry Lab (4 Credits)

L-T-P 0-0-8 Level: 300

Pre-requisite: None

CO	CO Statement	CL
CO1	Execute and perform experiments based on pH metry, potentiometry, conductometry and colorimetry.	Evaluate
CO2	Understand the operation principles of various instruments and perform experiments using them	Evaluate
CO3	Apply the concepts of qualitative and quantitative aspects in inorganic preparation	Apply
CO4	Synthesize metal complexes and characterize them by various physicochemical methods.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3

pH Metry: Acid-base titrations involving strong and weak acids/bases.
Conductometry: Acid-base titrations involving strong and weak acids/base, Determination of degree of ionization of weak electrolytes
Potentiometry: Acid-base titrations involving strong and weak acids/base, Determination of degree of ionization of weak electrolytes. Redox titrations.
Colorimetry: Verification of Beer-Lambert Law, Estimation of ferric iron by colorimetry, Estimation from real samples
Inorganic preparations: Preparation of Tris(oxalato)manganese(III), Tetrapyridinesilver(II) peroxidisulphate, Tris(acetylacetonato) iron(III), Bis(N,N-diethyldithiocarbamato)nitrosyliron(I), Optical isomers of tris(ethylenediamine)cobalt(III)chloride, Nitropentamminecobalt(III) chloride, Tri(acetylacetonato)manganese(III), Tris(thiourea) copper(I) sulphate, Phenyl lithium, Tetraphenyl lead, Ferrocene, Phosphonitrilic chloride

Recommended Textbooks

1. Gurtu, J. N., Gurtu, A., Advanced Physical Chemistry Experiments, 6th Ed.,Pragati Prakashan,2014.
2. Yadav, J. B., Advanced Practical Physical Chemistry, 36th Ed., Krishna Prakashan, 2016.
3. D.P Shoemaker, G.W Garland, J.W Nibler, Experiments in Physical Chemistry, 5th Edn., McGraw Hill.
4. B. P. Levitt, Findlay's Practical Physical Chemistry, 9 th Edn, Longman Group Ltd.
5. Vogel's textbook of quantitative chemical analysis, Fifth Edition
6. A.I. Vogel, A Text Book of Quantitative Inorganic Analysis, Longman, 1966
7. G. Pass, H. Sutcliffe. Practical Inorganic Chemistry 2nd edition, Chapman & Hill. 1974.
8. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Edn., Pearson Education, Noida, 2013.

24-808-0605 Visualization and Computing (3 Credits)

L-T-P 1-0-4 **Level: 300**

Prerequisites: None

CO	CO Statement	CL
CO1	Understand the structures using 3D visualization	Apply
CO2	Build molecule, biomolecules and unit cell	Apply
CO3	Extract structural information from available databases	Analyze
CO4	Calculate and analyse structures and protein ligand binding energies under MM	Analyze

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	1	1	0	0
CO2	0	2	1	1	1	1
CO3	0	3	2	2	1	2
CO4	0	3	3	3	3	3

Module I (15 hrs)

Introduction to cheminformatics, Graphical 3D-visualisation of the chemical world using various visualizer tools: Molecules, Biomolecules and Materials. Various file formats, Interconversion of various file formats.

Module II (15 hrs)

Building molecules, biomolecules and materials using softwares. Internal, Cartesian and fractional coordinate systems. Z-matrix, Unit cell and lattice.

Module III (15 hrs)

Introduction to databases – Crystallographic databases, Materials project, PDB database – PDB data, Secondary structure prediction, Fold recognition.

Module IV (15 hrs)

Molecular Mechanics - Force fields - energy calculation, minimization and analysis.

Module V (15 hrs)

Basics of structure based drug design- Docking - Molecular Recognition, Prediction of Protein-ligand interaction sites.

Recommended Text Books:

1. Leach, A.R. “Molecular Modelling Principles and Application, Longman”, 2001.
2. Haile, J.M. “Molecular Dynamics Simulation Elementary Methods,” John Wiley and Sons, 1997.
3. Satya Prakash Gupta, QSAR and Molecular Modeling, Springer - Anamaya Publishers, 2008.
4. Cramer, C. J., “Essentials of Computational Chemistry- Theories and Models”, 2nd Edition, Wiley, 2004
5. Jensen, F., “Introduction to Computational Chemistry”, 3rd Edition, Wiley, 2017.
6. Young, D., “Computational Chemistry – A Practical Guide”, Wiley, 2001.

24-808-0701 Inorganic Chemistry IV: Reaction Mechanism and Organometallic Chemistry (4 Credits)

L-T-P 4-0-0 Level: 400

Prerequisite: 24-808-0501 or equivalent

CO	CO Statement	CL
CO1	Understand the basic concepts and applications of organometallics.	Understand
CO2	Evaluate the structure, bonding and reactions of organometallic compounds and metallocenes.	Analyse
CO3	Predict the stability of organometallic compounds and metal clusters.	Apply
CO4	Explain the stability of transition metal complexes, their reactivity, and the mechanisms of ligand substitution	Analyze
CO5	Explain the application of reactions of organometallic complexes in homogeneous catalytic processes.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	0	0	3	2	2
CO2	3	0	0	3	2	2
CO3	3	0	0	3	2	2
CO4	3	0	0	3	2	2
CO5	3	0	0	3	2	2

Module I (12 hrs)

Organometallic Chemistry. Compounds with transition metal to carbon bonds: eighteen electron rule; classification of ligands, nomenclature, metal-metal multiple bonding, Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, EAN rule as applied to carbonyls, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. Preparation and structure of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni. π-acceptor behaviour of CO, synergic effect and use of IR data to explain extent of back bonding.

Module II (12 hrs)

σ donor ligands – metal alkyl, aryl complexes; σ donor/π acceptor ligands, – metal alkenyls, alkynyls, carbenes, carbynes, isocyanide, phosphines, fluxionality of ligands – structure, bonding, spectra, preparation and reactions.

σ, π donor/π acceptor ligands – olefin complexes, alkyne, allyl, enyl complexes

Metallocene- ferrocene, titanocene, zircanocene, arene complexes, cycloheptatriene, cyclooctatetraene, cyclobutadiene complexes, fluxionality of ligands – structure, bonding, preparation, reactions and spectroscopy.

Module III (12 hrs)
Metal–Metal bonds and Transition metal clusters; preparation, properties and spectroscopy. Parallels with nonmetal chemistry- isolobal analogy. Application of Wade-Mingos-Lauher rules in predicting the structure of organometallic clusters Organo-lithium aluminium, magnesium, zinc and titanium compounds – their preparations, properties, reactions, bonding and applications.
Spectral analysis and characterization of organometallic complexes.

Module IV (12 hrs)
Reaction Mechanism: Thermodynamic and kinetic consideration, formation constant and rate constant, inert and labile complexes, factors affecting the stability and lability of complexes.
Ligand substitution in octahedral complexes, mechanism of substitution reactions in octahedral complexes, dissociative, associative and interchange mechanism, energy profile of reactions, acid and base hydrolysis, factors affecting the rate of substitution reactions in octahedral complexes.
Ligand substitution in square planar complexes, mechanism of substitution reactions in square planar complexes, energy profile of reactions, the trans effect and its applications, theories for explaining trans effect, factors affecting the rate of substitution reactions in square planar complexes.
Electron Transfer Reactions: inner sphere and outer sphere mechanism, Marcus theory, photochemical reactions

Module V (12 hrs)
Reactions of organometallic complexes – Ligand cone angle, oxidative addition, reductive elimination, insertion, nucleophilic and electrophilic attack of coordinated ligands. Homogeneous catalysis using organometallic compounds: olefin hydrogenation, hydroformylation, Wacker process, Ziegler-Natta polymerisation, cyclo oligomerisation, olefin isomerisation, olefin metathesis, Monsanto acetic acid synthesis, Fischer-Tropsch process, hydrosilylation, coupling reactions in organic chemistry

Recommended Books :

1. Ch. Elschenbroich, A. Salzer, Organometallics – A Concise Introduction, VCH Publishers, 1989.
2. B. D. Gupta, A. J. Elias, "Basic Organometallic Chemistry", University Press, 2010.
3. Powell, Principles of Organometallic Chemistry, 2nd ed., ELBS, 1991.
4. J. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
5. Basolo, F, and Pearson, R.C., Mechanisms of Inorganic Chemistry, 2nd Ed., John Wiley & Sons, NY, 1967.
6. Crabtree, Robert H. The Organometallic Chemistry of the Transition Metals. 6th Ed., NY: John Wiley, 2014.
7. Miessler, G.L. & Tarr, D. A. Inorganic Chemistry, 5th Ed., Pearson Publication, 2013.
8. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3rd ed., ELBS, 1999.

24-808-0702 Organic Chemistry IV: Heterocyclic Compounds, Natural Products & Drug Development (4 Credits)

L-T-P 4-0-0 Level: 400

Pre-requisite: None

CO	CO Statement	CL
CO1	Device synthesis scheme for heterocyclic aromatic and nonaromatic organic compounds.	Apply
CO2	Elucidate structure and device synthesis for important natural products.	Apply
CO3	Understand various stages and processes involved in drug discovery and development.	Understand
CO4	Develop natural product-based drug molecules and characterization of complex natural products and biomolecules using spectroscopic techniques	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	2	2	3	2	2
CO2	2	3	2	3	3	2
CO3	2	2	2	3	2	2
CO4	2	2	2	3	2	2

Module I (13 Hrs)

Heterocyclic compounds: Nomenclature of three to seven-membered heterocyclic compounds. Five and six-membered heteroaromatic compounds containing one to four heteroatoms (N, O, S). Indole, quinoline and isoquinoline-structure, general preparation and chemical properties. Flavonoids, coumarin and anthocyanin- structure, properties and biological functions.

Alkaloids: Isolation and classification, isolation, and structure elucidation based on degradative reactions (quinine and atropine). Biosynthesis of quinine and papaverine.

Module II (12 hrs)

Terpenoids: Classification, biosynthesis. Structure and synthesis of abietic acid. Steroids: classification, biosynthesis. Structure and synthesis of cholesterol, conversion of cholesterol to progesterone, androsterone and testosterone. Fatty acids: structure, biosynthesis. Prostaglandins-classification, structure, biosynthesis and synthesis.

Module III (12 hrs)

Carbohydrates: Classification, configurational relationship of monosaccharides—aldotetroses, aldopentoses and aldohexoses. Structure and properties of D-Glucose—Open-Chain Structure, cyclic Structure. Configuration of D-Glucose, Haworth-Projections, conformations of D-glucose. Epimers, mutarotation and its mechanism. Lengthening and shortening of carbon chain of aldoses, Structure of Various Disaccharides—Maltose, Lactose, Cellobiose and Sucrose, Polysaccharides-Starch, Cellulose, Glycogen, Chitin and Heparin.

Preparation of alditols, glycosides (O, C, and N), and deoxysugars. Synthesis of Vitamin C from glucose.

Module IV (13 hrs)

Drug Discovery and Development: Introduction to various phases of drug discovery and development, targets in drug discovery. In-vitro screening systems. Structure-activity relationships, quantitative structure-activity relationships. Pharmacophore, pharmaco-dynamics and pharmaco-kinetics. Dose response parameters-LD50, ED50, LC50, EC50, MIC and MEC. Computer-aided drug design strategies-structure-based drug design, ligand-based drug design. Basics of clinical trials. Mechanism of drug action through examples: Taxol (anticancer agent), penicillin (antibiotic).

Natural product-derived drugs, Synthetic strategies towards plant-based drugs- diversity-oriented synthesis (DOS), biology-oriented synthesis (BIOS) and diverted-total synthesis (DTS).

Module V (10 hrs)

Application of spectroscopic techniques: 2D NMR spectroscopy, chiroptical spectroscopy, characterisation of natural products and biomolecules using spectroscopic techniques including 2D NMR- case study.

Recommended Text Books

1. I. L. Finar, Organic Chemistry Volumes 1 & 2, 6th ed., Pearson Education Asia, 2004.
2. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
3. N. R. Krishnaswamy, Chemistry of Natural Products; A Unified Approach, Universities Press, 1999.
4. S. P. Bhutani, Chemistry of Biomolecules, 2nd ed., CRC Press, 2020.
5. R. O. C. Norman, Principles of Organic Synthesis, 2nd ed., Chapman and Hall, 1978.
6. J. A. Joule, K. Mills, Heterocyclic Chemistry, 5th ed., Wiley, 1998.
7. A. Gürses, M.Açıkyıldız, K. Güneş , M. S. Gürses, Dyes and Pigments, Springer, 2016.
8. K. Stromgaard, P. Krogsgaard-Larsen, U. Madsen, Textbook of Drug Design and Discovery, 5th ed., 2017, Taylor & Francis Group.
9. B. E. Blass, Basic Principles of Drug Discovery and Development, Elsevier, 2015.

24-808-0703 Theoretical Chemistry III: Approximations and Chemical Bonding (4 Credits)

L-T-P 4-0-0 Level: 400

Prerequisite: 24-808-0404 (Quantum Mechanics) or equivalent.

CO	CO Statement	CL
CO1	Derive the Schrodinger equation for multielectronic atoms and interpret the results.	Apply
CO2	Derive the variational principle and perturbation theory, use them to calculate properties for simple systems of chemical interest.	Analyze
CO3	Explain Hartree-Fock Theory and semiempirical Huckel MO treatment and its application to polyelectronic molecules	Analyze
CO4	Classify various basis sets and justify its use for a specific problem	Analyze
CO5	Explain different chemical properties of molecules by drawing molecular orbitals and analyze and interpret the results to solve chemical puzzles.	Analyze

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	0	2	1	0
CO2	2	1	0	2	1	0
CO3	3	1	1	3	1	0
CO4	3	2	2	3	2	2
CO5	3	3	3	3	3	3

Module I (14 hrs)

Hamiltonian operators, Wave functions and energy of H like systems, Orbital functions, Postulate of electron spin-orbital and spin functions. Zeeman effect. Spin Orbitals and their construction, Antisymmetric wave functions, Pauli's antisymmetry principle. Many body problems, Born – Oppenheimer Approximations, Independent particle method, Drawbacks. Variational method – theory, proof and general treatment of linear variational problem- Application to systems such as Hydrogen, Helium and various other cases.

Module II (10 hrs)

Hamiltonian operator for multielectronic atom, Perturbation method: Time Independent perturbation for non- degenerate –first order, perturbation corrections to energy and wave functions, Application of this to various systems such as particle in a box, helium atom. Self-Consistent Field approximation- Hartree's proposal, Pauli's antisymm principle, Pauli exclusion principle, Electron spin, Constructing Antisymmetric spin incorporated wave functions for He, excited state of He – various electronic states, term symbols. Hartree-Fock Self Consistent Field method for multielectronic atoms. The Coulomb and Exchange Operators, The Fock Operator, Koopmans' theorem, Brillouin's theorem, Slater's treatment of complex atoms, Slater orbitals, Slater determinant and wave function.

Module III (8 hrs)

Chemical Bonding- Application to H_2^+, MO and VB treatment of H_2 molecule- Comparison. Concept of σ, σ*, π, π* orbitals and their characteristics, hybrid orbitals, calculation of coefficients of AO used in sp, sp^2 and sp^3 hybrid orbitals, interpretation of geometry, Valence bond model of H_2, Hybridisation of H_2O, BF_3, NH_3 and CH_4 Hartree Fock -Roothaan method - LCAO approximation - Restricted HartreeFock (RHF) for closed shell systems, Restricted open HF (ROHF), and Unrestricted HF (UHF) methods, Empirical, Semi empirical and ab initio methods. Basis functions- Slater Type Orbital and Gaussian Type Orbitals. Contracted and primitive. Basis sets. Minimal, multiple zeta, split-valence, polarized and diffused. Pople style basis sets, designation of basis set size –Dunnings correlation consistent basis sets, Relativistic effects - Effective core potential, ECP.

Module IV (13 hrs)

HMOT: Pi bonding in simple molecules, HMO method for linear conjugated hydrocarbons, linear, cyclic, polycyclic, heterocyclic; ethylene, 1,3-butadiene, allyl radical, cation and anion, aromatic hydrocarbons, cyclopropenyl systems, cyclobutadiene, benzene, naphthalene, thiophene. Calculation of charge distribution, bond orders and reactivity. QMOT: Applications of Molecular Orbital Theory in Understanding reactions and Mechanisms. Qualitative MO theory. Group orbitals. Frontier Orbitals, Substituent effects on frontier orbitals, HSAB concept, Nucleophiles and Electrophiles, Perturbation theory of reactivity. Application of Frontier Orbital theory in studying ionic and radical reactions, Ambident electrophiles, α-effect.

Module V (30 hrs)

Computational calculations listed below using available Molecular orbital theory suite of programme package: Constructing molecular structures or models; Molecular geometry optimization; Conformational analysis; Thermodynamic and spectroscopic properties; Molecular orbital analysis; Electron density and electrostatic potential map.

Recommended Text Books:

1. Atkins, P.W. and Paula, J. Physical Chemistry, 8th Ed., Oxford Press, 2006.
2. Szabo, A.; Ostlund, N. S. "Modern Quantum Chemistry: Introduction to Advanced Structure theory", Dover Publications, 1996.
3. Levine, I. N. "Quantum Chemistry", 7th Ed., Pearson Education Inc., 2014.
4. McQuarrie, D. A., "Quantum Chemistry", 2nd Ed.,University Science Books, 2008.
5. Pillar, F. L. "Elementary Quantum Chemistry", 2nd Ed., Dover Publication, 2001.
6. Chandra, A. K., "Introduction to Quantum Mechanics", 4th Ed., Tata McGraw-Hill, New Delhi, 2003.
7. Prasad, R. K., "Quantum Chemistry", 4th Ed., New Age International, 2009.
8. Cramer, C. J., "Essentials of Computational Chemistry- Theories and Models", 2nd Ed., Wiley, 2004.

9. Jensen, F., "Introduction to Computational Chemistry", 3rd Ed., Wiley, 2017.

10. Young, D., "Computational Chemistry – A Practical Guide", Wiley, 2001.

11. Anslyn, E. V.; Dougherty, D. A. Modern Physical Organic Chemistry. University Science Books.

12. Foresman, J. and Frisch, A.," Exploring chemistry with electronic structure methods", Guassian Inc, 2000.

24-808-0704 Scientific Writing and Presentation (2 Credits)

L-T-P 1-0-2 Level: 500

Prerequisite: None

CO	CO Statement	CL
CO1	Apply data analysis tools and logical reasoning in the in-depth study and critical analysis of primary literature data	Apply
CO2	Use basic graphical and sketching tools for data analysis and presentation	Analyze

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	2	2	2	3	3
CO2	1	2	2	2	3	3

Soft Skills: Operating Systems, Document Preparation-Microsoft Word and LaTex. Graph/plotting softwares – Excel, ORIGIN, MATLAB, Veusz; Presentation tools - Powerpoint, , Reference management softwares- Endnote,Mendeley, Refworks
Subject Specific Soft Skills – Building / drawing Molecules - ChemDraw, ChemSketch.

Literature search- Introduction to databases – Scifinder, Reaxys, and Cambridge Structural Databases. Web browsing: various publisher sites such as ACS, RSC, Wiley, Science Direct, Scopus, Web of Science, UGC-INFLIBNET, Shodh Sindu, Shodh Ganga Plagiarism software.

Recommended Books

1. John M. Swales & Christine B. Feak, Academic Writing for Graduate Students, 3rd Edition, Michigan Publishing, 2012.
2. Stephen Bailey, Academic Writing, A Handbook for International Student,5th Edition, Routledge, Taylor & Francis, 2018.
3. Kothari, C. K., Research Methodology-Methods and Techniques, 2nd Ed., New Age International, New Delhi, 2023
4. Montgomery, D. C., Design & Analysis of Experiments, 5th Ed., Wiley India (2007).

24-808-0705 Polymer Chemistry (4 Credits)

L-T-P 4-0-0 Level: 400

Pre-requisite: None

CO	CO Statement	CL
CO1	To gain basic knowledge about various Polymerization mechanism	Understand
CO2	To understand various types of polymerisation techniques and processing.	Understand
CO3	To get knowledge on polymer characterization	Analyze
CO4	To get an idea about the functional polymers and the applications for advanced technologies	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	0	0	3	2	2
CO2	3	0	0	3	2	2
CO3	3	0	0	3	3	2
CO4	3	0	0	3	3	2

Module I (10 hrs)

Introduction. Nomenclature. Classification. Molecular weight. Physical states. Crystalline and amorphous behaviour. Thermal transition. Mechanical properties. Chemical Bonding and Polymer Structure.

Module II (14 hrs)

Polymerization Mechanism. Free radical addition polymerization. Kinetics and mechanism. Chain transfer. Molecular weight distribution and molecular weight control. Cationic and anionic polymerization. Polymerization without termination. Living polymers. Step Growth polymerization. Kinetics and mechanism. Linear Vs cyclic polymerization, Group Transfer, metathesis and ring opening polymerization. Copolymerization. Copolymerization equation, Q-e scheme, Gelation and Crosslinking.

Module III (10 hrs)

Polymerization techniques and Processing. Bulk Solution, melt, suspension, emulsion and dispersion techniques. Elastomers. Fibers. Plastics.

Module IV (14 hrs)

Polymer Characterization. Molecular weights. Concept of average molecular weights, Determination of molecular weights. Gel Permeation Chromatography and Light scattering techniques. Molecular weight distribution. Crystalline and amorphous states. Glassy and Rubbery States. Glass transition and crystalline melting. Degree of Crystallinity, X-Ray diffraction analysis. Thermal analysis of polymers. TG/DTG, DTA/DSC, Spectroscopy of polymers. Microstructure determination by IR, Raman, UV, NMR and MS techniques. Solid State NMR.

Module V (12 hrs)

Functional Polymers. Porous Organic Polymers, Covalent organic framework, Dendritic polymers, Conducting polymers, Redox polymers, Luminescent polymers. Liquid Crystalline polymers.

Industrial polymers. Polyethylene, polystyrene. PVC, PAN, Poly(vinyl carbazole). Silicone polymers.

Polymers for Advanced Technologies. Sensor Applications. Applications in Electronics and Energy – Electrically Conductive Polymers, Polymeric Batteries, Organic Photovoltaic Polymers. Photonic Polymers – Nonlinear Optical polymers, Light Emitting Diodes.

Recommended Books :

1. F. W. Billmeyer Jr., Textbook of Polymer Science, John Wiley and Sons, N.Y. 1991.
2. V. R. Gowarikar, Polymer Chemistry, New Age International Pvt. Ltd., New Delhi, 2010
3. George Odian, Principles of Polymerization, 4th Edn., Wiley, 2004
2. J.M.G Cowie. Polymers, Physics and Chemistry of Modern Materials. Blackie. London, 1992.
3. R.J.Young, Principles of Polymer Science, 3rd ed., Chapman and Hall. N.Y. 1991.
4. R. O. Ebewele, Polymer Science and Technology, CRC Press. N.Y., 1996
5. P.J. Flory, A TextBook of Polymer Science, Cornell University Press, Ithacka, 1953.
6. F. Ullrich, Industrial Polymers, Kluwer, N.Y, 1993.
7. H.G.Elias, Macromolecules, Vol. I & II, Academic, N.Y. 1991.
8. J.A.Brydson, Polymer Chemistry of Plastics and Rubbers, ILIFFE Books Ltd., London, 1966
9. J.R.Fried, Polymer Science and Technology, Pearson Education Inc., New Jersey, 2014.

24-808-0706 SUPRAMOLECULAR CHEMISTRY AND APPLICATIONS (4 Credits)

L-T-P 4-0-0 Level: 400

Pre-requisite: None

CO	CO Statement	CL
CO1	Explain the structural features of any given supramolecular system	Analyze
CO2	Analyze the type of possible interactions in any given host guest assembly	Analyze
CO3	Predict the photochemical and Photophysical behavior in constrained media	Analyze
CO4	Analyze the change in electronic structure of the supramolecular systems based on the interaction with the host	Evaluate
CO5	Utilize the studied systems for applications for catalysis, solar energy conversions, drug delivery etc.	Evaluate

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	3	2	2
CO2	3	2	1	3	2	2
CO3	3	2	1	3	2	1
CO4	3	2	1	3	2	1
CO5	3	2	1	3	2	2

Module I (12 hrs)

Self-assembly and preorganization, Supramolecules non-covalent forces and interactions in supramolecules–Hydrogen bonding, π Effects, dipole interactions, induced dipole interactions, hydrophobic interactions. Solvent Effects, Thermodynamics of binding phenomena.

Module II (12 hrs)

Molecular Recognition – Host guest interactions, Macrocycles, Structure, Preparation and Properties of crown ethers, cryptates, cryptands, carcerands, calixarenes, cyclodextrins, fullerenes, dendrimers, rotaxanes, cucurbiturils.

Module III (12 hrs)

Complex Architectures – Self-assembly, Complementarity and Reorganization, Coordination driven self-assembly of supramolecular two and three dimensional architectures, kinetic and thermodynamic aspects, COF, MOF and their applications.

Module IV (12 hrs)

Photochemistry in constrained media- photophysical, photochemical processes, energy transfer, electron transfer. Effect of structural features and interactions on energy levels.

Module V (12 hrs)

Applications – photocatalysis, water splitting, solar cell, CO_2 reduction, drug delivery, sensors, gas separation and storage.

Recommended Books:

1. Jonathan W. Steed, Jerry L. Atwood, Supramolecular Chemistry, Wiley, 2013.
2. J. M. Lehn, Supramolecular Chemistry: Concepts and Perspectives, Wiley, 1995
3. E.V. Ansyln, D. A. Dougherty, Modern Physical Organic Chemistry, University Press, 2006.
4. P. Klan and J. Wirz, Photochemistry of Organic Compounds,
5. Nicholas J. Turro, V. Ramamurthy, J.C. Scaiano, Modern Molecular Photochemistry of Organic Molecules,
6. Christian S. Diercks, Markus J. Kalmutzki, and Omar M. Yaghi, Introduction to Reticular Chemistry: Metal-Organic Frameworks and Covalent Organic Frameworks, Wiley, 2019.
7. Shengqian Ma, Jason A Perman, Elaboration and Applications of Metal-Organic Frameworks, World Press, 2018.

24-808-0801 Research Proposal Writing (2 Credits)

L-T-P 1-0-2 Level: 500

Prerequisite: 24-808-0704 or equivalent

CO	CO Statement	CL
CO1	Develop skill in writing a scientific proposal/ Review	Create

Research Proposal and Review Writing: Components of a proposal, Work plan, Budget and funding. Types of reports – Communication, full length article and reviews. Publication process, selection of journals, citation index, impact factor, h-index.

Recommended Books

1. John M. Swales & Christine B. Feak, Academic Writing for Graduate Students, 3rd Edition, Michigan Publishing, 2012.
2. Stephen Bailey, Academic Writing, A Handbook for International Student,5th Edition, Routledge, Taylor & Francis, 2018.
3. Kothari, C. K., Research Methodology-Methods and Techniques, 2nd Ed., New Age International, New Delhi, 2023
4. Montgomery, D. C., Design & Analysis of Experiments, 5th Ed., Wiley India (2007).

B. Sc Honors

24-808-0802 Project (4 Credits)

L-T-P 0-0-8

B. Sc Honors with Research

24-808-0802 Project (12 Credits)

L-T-P 0-0-24

Students will undertake the project work according to the regulations of the FYUGP and as approved by the Department Council

24-808-0803 Advanced Analytical and Instrumentation Techniques I (4 Credits)

L-T-P 4-0-0 Level: 500

Prerequisite: None

CO	CO Statement	CL
CO1	Understand the basic principles and instrumentation aspects of various electroanalytical, chromatographic, and thermo-analytical techniques	Understand
CO2	Interpret the data obtained from analytical techniques	Evaluate
CO3	Use the electroanalytical, chromatographic, and thermo-analytical techniques for qualitative and quantitative evaluations	Analyze

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	2	2	2	2
CO2	3	2	2	2	2	1
CO3	3	3	2	2	2	2

Module I (14 hrs)

Potentiometry: different types of indicator electrodes, limitations of glass electrode, applications in pH measurements, other types of ion selective electrodes, solid, liquid, gas sensing and specific types of electrodes, biomembrane, biological and biocatalytic electrodes as biosensors, importance of selectivity coefficients. CHEMFETS- importance of specially designed amplifier systems for ion selective electrode systems. Potentiometric titrations- types and applications.

Module II (14 hrs)

Electrogravimetry- electrogravimetry without potential control, controlled potential electrogravimetry, applications. Coulometry- constant current and constant potential coulometry, applications- primary and secondary coulometry, advantages of coulometric titrations Conductance measurement – conductometric titrations.

Module III (14 hrs)

Polarography – current – voltage curve, DME-components of polarographic current, supporting electrolyte, polarographic maxima. Half-wave potential, Applications of Polarography. Voltammetry - different types, Theory and applications. Stripping analysis. Amperometric titrations – Different types and Applications Impedance spectroscopy, Voltammetric sensors – individual and simultaneous analysis-Case study.

Module IV (12 hrs)

Thermal methods of Analysis TG, DTA and DSC - Instrumentation and Theory – Factors affecting TGA - effect of atmosphere on DTA. TG of copper sulphate pentahydrate and calcium oxalate monohydrate. Application of thermal methods for identification of substances.

Module V (18 hrs)

Solvent extraction and Solid phase extraction, Basic principles of solvent extraction Distribution law-Liquid-liquid extractions, synergistic extraction, Batch extraction, continuous extraction, Counter current extraction, super critical fluids

Chromatography: Basic principles, adsorption, differential migration, effect and choice of stationary and mobile phases, Classification of chromatographic techniques., Thin layer chromatography, Paper chromatography, column chromatography, gas chromatography, ion exchange chromatography, gel permeation chromatography, supercritical fluid chromatography and size exclusion chromatography, Important applications of chromatographic techniques.

Recommended Books:

1. J.M. Mermet, M. Otto, R. Kellner, Analytical Chemistry, Wiley-VCH, 2004.
2. D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8th Edn., Saunders College Pub., 2007.
3. J.G. Dick, Analytical Chemistry, R.E. Krieger Pub., 1978.
4. J.H. Kennedy, Analytical Chemistry: Principles, Saunders College Pub., 1990.
5. G.H. Jeffery, J. Bassett, J. Mendham, R.C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Edn., John Wiley& sons,1989.
6. C.L. Wilson, D.W. Wilson, Comprehensive Analytical Chemistry, Elsevier, 1982.
7. G.D. Christian, J.E. O'Reilly, Instrumental Analysis, Allyn & Bacon, 1986.
8. R.A. Day, A.L. Underwood, Quantitative Analysis, Prentice Hall, 1967.
9. H.A. Laitinen, W.E. Harris, Chemical Analysis, McGraw Hill, 1975.
10. F.W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, Blackwell Science, 2000.
11. Contemporary Instrumental Analysis, Kenneth A. Rubinson, Judith F. Rubinson, Prentice Hall, New Jersey, 2000.
12. Wilson & Wilson's, Comprehensive Analytical Chemistry, Volume 47, Modern Instrumental Analysis, Edited by S. Ahuja, N. Jespersen, Reed Elsevier India Private Ltd., Noida, 2006.
13. Journal of Chromatography Library, Volume 3, Liquid Column Chromatography-A Survey of Modern Techniques and Applications, Edited by Z. Deyl, K. Macek, J. Janak, Elsevier Scientific Publishing Company, Amsterdam, 1975.
14. Gas Chromatography, John Willett, John Wiley & Sons, Singapore, 1991.
15. Fundamentals of Analytical Chemistry, Doughlas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch, 9th Ed., Cengage Learning, 2014.

24-808-0805 Electronic Structure from Molecules to Solids (4 Credits)

L-T-P 4-0-0 Level: 500

Prerequisites: 24-808-0601 or equivalent.

CO	CO Statement	CL
CO1	Construct fragment molecular orbitals, correlation diagrams and interaction diagram.	Analyze
CO2	Explore the effects of symmetry, overlap, and electronegativity in generating the molecular orbital.	Analyze
CO3	Correlate the MO and properties and thus quantify the reactivities	Analyze

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	2	1	0
CO2	3	2	1	2	1	0
CO3	3	3	2	2	2	2

Module I (14 hrs)

Atomic orbitals, Orbital Interactions leading to molecular orbitals, Molecular orbital coefficients – Degenerate and Non-degenerate Interaction, Electron density distribution. Symmetry consideration, Noncrossing rule. Molecular orbitals of diatomic molecules and electronegativity perturbation.

Module II (12 hrs)

Molecular orbital construction from Fragment orbitals- Linear and circular Hn, Geometrical perturbation and Walsh diagrams. Extending the results to polyenes and cyclic conjugated systems and Huckel's rule of aromaticity.

Module III (12 hrs)

Construction of molecular orbitals of small fragments and their shapes – AH, AH_2, AH_3 and AH_4. Jahn-Teller distortion, Through bond interactions.

Molecules with two heavy atoms- A_2H_6, A_2H_4, and A_2H_2. Polarization and substituent effects.

Module IV (10 hrs)

Transition metal complexes- Octahedral ML_6, square planar ML_4, C_{4v} ML_5 and C_{2v} ML_3 fragments. Isolobal analogy- Generation of isolobal fragments and illustration.

Module V (12 hrs)

Orbitals and Bands, Bloch functions, Reciprocal space and the k quantum number, Band structure – one-dimensional systems, Band width, Fermi level, Higher dimensions, Density of States (DoS)- Basic electron partitioning, Pierl's distortion, Folding Bands, Crystal Orbital Overlap Population (COOP), Constructing and analysing the band structure- Case study –Bulk solid and surface (Adsorption).

Recommended Text Books:

1. T. A. Albright, J. K. Burdett, M.-H. Whangbo, Orbital Interactions in Chemistry, 2nd ed., John Wiley and Sons, Inc., Hoboken, New Jersey, 2013.
2. I. Flemming, Molecular Orbitals and Organic Chemical Reactions, Students ed., Wiley, 2009.
3. A. Rauk, Orbital Interaction Theory of Organic Chemistry, 2nd ed., WileyBlackwell, 2000.
4. W. L. Jorgensen, L. Salem, The Organic Chemist's Book of Orbitals, Academic Press, 1973.

24-808-0806 Advanced Organic Chemistry I (4 Credits)

L-T-P 4-0-0 Level: 500
Prerequisites: 24-808-0602 or equivalent

CO	CO Statement	CL
CO1	Analyze the conformational effects on the reactivity of reactions.	Apply
CO2	Analyze the reagents and conditions for the synthesis of specific target molecules.	Analyse
CO3	Describe strategies for the stereospecific /stereoselective organic transformations towards chiral target molecules.	Apply
CO4	Construct a synthetic pathway for simple to complex organic molecules by retrosynthetic approach.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	1	3	2	1	1
CO2	2	1	3	2	1	1
CO3	1	3	3	2	1	1
CO4	1	3	3	2	1	1

Module I (14 hrs)
Reaction mechanisms and conformational effects on reactivity - Ester hydrolysis, alcohol oxidations, S_N2 reactions, elimination reactions, epoxidation by intramolecular closure of halohydrins, strain-modulated reactivity, epoxide openings (S_N2), electrophilic additions to olefins, rearrangement reactions, conformational and stereoelectronic effects on reactivity.
Stereoselective reactions of cyclic compounds. Reactions on small rings. Stereochemical control in six-membered rings. Stereochemistry of bicyclic compounds. Reactions with cyclic intermediates/transition states.

Module II (12 hrs)
Asymmetric Synthesis: Introduction to asymmetric synthesis, principle, general strategies, chiral pool strategy, chiral auxiliaries, chiral reagents – Binol derivatives of $LiAlH_4$, chiral catalysts – CBS catalyst. Stereospecific and stereoselective synthesis, determination of enantiomeric and diastereomeric excess. Stereoselective nucleophilic additions to acyclic carbonyl groups- Cram’s Rule, Felkin-Ahn Model, Effect of chelation on selectivity. Application of asymmetric synthesis in the industrially relevant molecules such as L-DOPA, (S)-metolachlor and menthol.

Module III (10 hrs)
Protecting groups- protection and deprotection of hydroxyl, carboxylic acids, and carbonyls in aldehydes and ketones, amines, alkenes and alkynes. Chemo- & regioselective protection and deprotection. Functional group equivalents, reversal of reactivity (Umpolung).

Module IV (14 hrs)

Disconnection approach-introduction to retrosynthesis, basic principles, synthons, and synthetic equivalents. Monofunctional and bifunctional disconnection, One group C-X and two groups C-X disconnections, one group C-C and two groups C-C disconnections. Computers in organic synthesis – introduction to softwares –SYNTHIA, MAPOS, AiZynthFinder.

Module V (10 hrs)

Retrosynthetic analysis: Longifoline, Corey lactone, Djerassi - Prelog lactone and D-luciferin. Application of AiZynthFinder to retrosynthetic analysis.

Recommended Text Books

1. P. S. Kalsi: Stereochemistry, Conformation and Mechanism, 3rd Edn., New Age Publications.
2. E. L. Eliel and S. H. Wilen: Stereochemistry in Organic Compounds, 1994, John Wiley.
3. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
4. P. S. Kalsi, Stereochemistry, Conformation and Mechanism, 9th ed., New Age Publications, 2017.
5. S. Warren, Organic Synthesis: The Disconnection Approach, 2nd ed., John Wiley, 2008.
6. E. Robert, Gawley, J. Aube, Principles of Asymmetric Synthesis, 2nd ed., Elsevier, 2012.
7. T.W. Greene, P. G. M. Wuts, Protecting Groups in Organic Synthesis, 2nd ed., John Wiley, 1991

24-808-0807 Materials Chemistry (4 Credits)

L-T-P 4-0-0 Level: 400
Prerequisites: None

CO	CO Statement	CL
CO1	To acquire basic knowledge on various types of materials	Understand
CO2	To gain insight on the structure – property relationship of different materials.	Understand
CO3	To get knowledge on various characterization techniques.	Analyze
CO4	To get an idea about the materials in advanced technological applications	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	0	0	3	2	2
CO2	3	0	0	3	2	2
CO3	3	0	0	3	3	2
CO4	3	0	0	3	3	2

Module I (12 hrs)
Chemistry of Materials. Ionic and covalent solids. Molecular and metallic solids. Amorphous and crystalline materials. Crystalline state. Structural organization of crystalline solids-theories of bonding. Crystal structures. Imperfections in crystal structures.
Semiconductor materials- properties and types of semiconductors. Structure and Bonding of semiconductor materials. Silicon based semiconductors. II-VI (wide band gap) and III-V (narrow band gap) compound semiconductors. Electrical, optical and magnetic properties of semiconductor materials. Preparation and properties of ZnO, ZnS, CdS, CdTe, Ga-As, In-S, Cu-In-S. Application in photovoltaic devices.

Module II (10 hrs)
Polymer Materials- classification and nomenclature of polymers. Methods of Polymerization. Structure–property relationships. Plastics and elastomers. Viscoelastic behaviour. Rubber like elasticity. Crystalline and amorphous polymers. Glass transition temperature and crystalline melting. Functional Polymers.

Module III (12 hrs)
Nanomaterials. Materials in the nanodomain. Zero, one- and two-dimensional materials. Particle size dependent change in properties of materials. Metals in the nanodomain. Gold and silver nanoparticles. Preparation, properties and applications. Core shell structures. Semiconductor nanoparticles. Quantum dots. ZnO, ZnS, CdS and CdSe quantum dots.
Electrical and optical properties. Nano domains of Carbon-fullerenes, carbon nanostructures, graphene, graphene quantum dots.

Module IV (14 hrs)
Characterization of Materials. Optical Microscopy- Principles, instrumentation and application of confocal Raman microscopy, SPM/STM. Electron microscopy- SEM, FESEM, TEM. Principles,

instrumentation and applications. Surface and core level techniques- Photoelectron spectroscopy - X-Ray and UV. Thermal methods- TG/DTG, DTA, DSC, DMA. X-Ray Diffraction

Module V (12 hrs)
Materials in Advanced Technology. Organic Polymer Semiconductors, Solid ionic conductors - Advanced materials for energy generation and energy storage. Porous membranes. Optical and photonic materials.

Recommended Books:

1. B. D. Fahlman, Materials Chemistry, 2nd ed. Springer, Heidelberg, 2011.
2. Harry R. Allcock, Introduction to Material Chemistry, John Wiley & Sons, Inc., New Jersy, 2008
3. R. Zallen, Physics of Amorphous Solids, Wiley, New York, 1983.
4. R. J. Borg, G. J. Dienes, The Physical Chemistry of Solids, Academic Press, Boston, 1993.
5. D. Kingery, H. K. Bowen, D. R. Uhlmann, Introduction to Ceramics, 2nd ed., Wiley, New York, 1992.
6. J. M. J. Cowie, Polymers. Physics and Chemistry of Modern Materials, 3rd ed., CRC Press, Boca Raton, 2007.
7. S. O. Kasap, Principles of Electronic Materials and Devices, Mc Graw Hill, 2006

24-808-0808 Transition Metals: Chemistry and Applications in Organic Synthesis (4 Credits)

L-T-P 4-0-0 Level: 400

Prerequisites: 24-808-0602 or equivalent

CO	CO Statement	CL
CO1	Describe the structure, bonding and properties of transition metal complexes.	Understand
CO2	Predict and explain the principle and mechanism involved in transition metal-mediated transformations.	Apply
CO3	Construct organic molecules for various applications using palladium reagents.	Apply
CO4	Predict the structure and reactions of various metal-carbene complexes.	Apply
CO5	Apply transition metal complexes for various asymmetric transformations	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	1	2	2	1	1
CO2	3	1	2	3	1	2
CO3	1	1	3	3	1	2
CO4	3	1	3	3	1	2
CO5	1	1	3	3	1	2

Module I (12 hrs)

Basic concepts in organometallic chemistry: Introduction, 18 electron rule and its limitations, electron counting with examples, oxidation state, types of ligands, bonding, back-bonding. Formation of transition metal complexes, coordination number and geometry. s-Bonded and p-bonded organometallic compounds.

Module II (12 hrs)

Mechanisms involved in transition metal chemistry: Oxidative addition, reductive elimination, transmetallation, migrative insertion, β-hydride elimination, nucleophilic and electrophilic attack on transition metal complexes. C-H activation. Catalytic mechanism of hydrogenation and hydroformylation. Single electron transfer and radical reactions. Homogeneous and heterogeneous catalysis.

Module III (14 hrs)

Reactions mediated by palladium-based reagents: Characteristics of organopalladium compounds, catalysts and precursors, mechanistic features of cross-coupling reactions, reactivity of substrates, selectivity. Palladium catalysed coupling reactions: Corriu-Kumada reaction, Hiyama reaction, Suzuki coupling, Sonogashira coupling, Heck reaction, Buchwald–Hartwig coupling, Negishi coupling, Stille coupling. Miscellaneous reactions catalysed by palladium- Direct arylation, cyanation, carbonylation, Tsuji-Trost allylic substitution, α-allylic alkylation and α-fluorination.

Module IV (12 hrs)
Transition metal carbene complexes: Structure and properties. Fischer carbene complexes-preparation and reactions. Schrock carbene complexes-preparation and reactions. Non-stabilised carbene complexes. Metathesis process of carbene complexes

Module V (10 hrs)
Transition metals in asymmetric catalysis: Asymmetric catalysis in metathesis, epoxidation, allylation, hydroformylation, isomerisation of allylic amines, hydrocyanation, hydrogenation, Heck reaction and Pauson–Khand reaction.

Recommended Text Books

1. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals, 6th Edn., John Wiley & Sons, 2014.
2. L. S. Hegedus, B. C. G. Soderberg, Transition Metal in the Synthesis of Complex Organic Molecules, 3rd Edn., University of Science Books, 2010.
3. D. Astruc, Organometallic Chemistry and Catalysis, Springer, 2007.
4. J. Tsuji, Transition Metal Reagents and Catalysts: Innovations in Organic Synthesis, John Wiley & Sons, 2002.
5. I. Omae, Applications of Organometallic Compounds, John Wiley & Sons, 1998
6. R. Bates, Organic Synthesis Using Transition Metals, 2nd Edn., John Wiley & Sons, 2012.
7. B. Gabriele, Organic Synthesis *via* Transition Metal-Catalysis, MDPI, 2022.
8. K. Grela, Olefin Metathesis, John Wiley & Sons, 2014.

24-808-0901 Advanced Analytical and Instrumentation Techniques II (4 Credits)

L-T-P 4-0-0 **Level: 600**

Prerequisites: None

CO	CO Statement	CL
CO1	Gain an in-depth understanding of working principles of advanced analytical and surface characterization techniques.	Understand
CO2	Choose and optimize the right techniques and instrumentation configuration for a particular analysis	Evaluate
CO3	Analyse the data for differentiation and quantitative evaluation of analytes and surfaces	Analyse
CO4	Predict the structure and reactions of various metal-carbene complexes.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	2	2	2	2
CO2	2	3	2	1	2	1
CO3	3	2	2	3	2	2

Module I (14 hrs)

Gas chromatography – basic instrumental set up-inlets, carriers, columns, detectors and comparative study of TCD, FID, ECD, NPD and MS. Qualitative and quantitative studies using GC, Preparation of GC columns, packet columns and capillary columns, selection of stationary phases of GLC, Choosing the parameters-Temperature, Length of the column, Sample size, Flow rate, CHN analysis by GC, Case study.

Module II (14 hrs)

Capillary electrophoresis-migration rates and plate heights, instrumentation, sample introduction, detection methods, applications. Capillary gel electrophoresis. Capillary isotachophoresis. Isoelectric focusing.

Capillary electro chromatography-packed columns. Micellar electro kinetic Chromatography.

Module III (16 hrs)

Separation process, Eddy diffusion, Mass transfer, Longitudinal diffusion, Retention parameters in HPLC-Capacity factor, Retention time, Retention volume, Peak width, Total number of theoretical plates, Height equivalent of a theoretical plate, Resolution and retention time, Solvent delivery systems, Detectors

Instrumentation and functioning of HPLC, Types of HPLC - Modes of separation in HPLC- adsorption chromatography, reversed phase chromatography, ion pair chromatography, ion exchange chromatography Solubility and retention in HPLC. Method development in HPLC - Selection of mobile phase and optimization, Preparation of sample, Selection of column and solvent, HPLC method validation, HPLC Analysis -Case study Dos and Don’ts in HPLC - Troubleshooting in HPLC

Module IV (14 hrs)
Measurement of alpha, beta, and gamma radiations, neutron activation analysis and its applications. Principle and applications of isotope dilution methods, Radioimmunoassay (RIA), Immunoradiometric assay (IRMA), Enzyme linked immunosorbent assay (ELISA)-Principles and practical aspects

Module V (14 hrs)
Chemical Analysis of surfaces: Surface preparations-ion scattering spectrometry secondary ion scattering microscopy (SIMS)-Auger election spectroscopy-ESCA instrumentation and application. Electron Microscopies, Basic principles of TEM and SEM, Elemental analysis, XRD, Scanning probe microscopies an overview, Basic principles of AFM and STM, Case study.

Recommended References:

1. J.M. Mermet, M. Otto, R. Kellner, Analytical Chemistry, Wiley-VCH, 2004.
2. D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8th Edn., Saunders College Pub., 2007.
3. J.G. Dick, Analytical Chemistry, R.E. Krieger Pub., 1978.
4. J.H. Kennedy, Analytical Chemistry: Principles, Saunders College Pub., 1990.
5. G.H. Jeffery, J. Bassett, J. Mendham, R.C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Edn., John Wiley& sons,1989.
6. C.L. Wilson, D.W. Wilson, Comprehensive Analytical Chemistry, Elsevier, 1982.
7. G.D. Christian, J.E. O'Reilly, Instrumental Analysis, Allyn & Bacon, 1986.
8. R.A. Day, A.L. Underwood, Quantitative Analysis, Prentice Hall, 1967.
9. H.A. Laitinen, W.E. Harris, Chemical Analysis, McGraw Hill, 1975.
10. F.W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, Blackwell Science, 2000.
11. Contemporary Instrumental Analysis, Kenneth A. Rubinson, Judith F. Rubinson, Prentice Hall, New Jersey, 2000.
12. Wilson & Wilson's, Comprehensive Analytical Chemistry, Volume 47, Modern Instrumental Analysis, Edited by S. Ahuja, N. Jespersen, Reed Elsevier India Private Ltd., Noida, 2006.
13. Journal of Chromatography Library, Volume 3, Liquid Column Chromatography-A Survey of Modern Techniques and Applications, Edited by Z. Deyl, K. Macek, J. Janak, Elsevier Scientific Publishing Company, Amsterdam, 1975.
14. Gas Chromatography, John Willett, John Wiley & Sons, Singapore, 1991.
15. Fundamentals of Analytical Chemistry, Doughlas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch, 9th Ed., Cengage Learning, 2014.

24-808-0902 Advanced Instrumentation Lab (4 Credits)

L-T-P 0-0-8 Level: 600

Prerequisites: None

CO	CO Statement	CL
CO1	Understand the operation principles of various instruments and perform experiments using them	Evaluate
CO2	Quantitative estimation of chemicals using various instruments	Apply
CO3	Estimate essential material properties	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	3	3	3	2	2
CO2	2	3	3	3	2	2
CO3	2	3	3	2	2	2

Module 1: (30 hours)
Colourimetry, UV-VIS spectroscopy and Diffuse reflectance spectroscopy: hands on training on the instrument, preparation of stock solutions, verification of Beeer-Lambertz law, Estimation of unknown concentration, establish correlation between molecular structure and spectrum, Band Gap Estimation of thin films, smartphone spectroscopy and comparison with colorimetry and UV-VIS spectroscopy
Fluorescence spectroscopy: Emission Excitation spectral analysis, Fluorescence quantum yield, fluorescence lifetime, quenching

Module II: (20 hours)
Refractometry and Polarimetry: hands on training on the instrument, preparation of stock solutions, estimation of refractive index and optical activity, estimation of unknown concentration, analysis of food samples

Module III (30 hours)
vibrational spectroscopy: hands on training on the instrument, preparation of samples, IR and Raman spectroscopic characterization of organic and inorganic samples, assignment of peaks to functional groups, spectral processing, data processing, chemometry and machine learning tools., preparation of nanomaterials of surface enhanced Raman spectroscopy, comparative study of Raman and SERS

Module IV: (20 hours)
Cyclic voltammetry: determination oxidation-reduction potentials, HOMO and LUMO levels
TGA-DTA Thermal analysis of samples
Gas chromatography and high performance liquid chromatography: sample preparation, separation, qualitative and quantitative analysis

Module V (20 hours)
Estimation of water quality parameters: pH, conductivity, Total Dissolved Solids, hardness, turbidity, Dissolved oxygen, COD, chloride

1. J. N. Gurtu, and A. Gurtu Advanced Physical Chemistry Experiments, 6 th Edn., Pragati Prakashan, 2014.
2. Krishna Chattopadhyay and Manas Mandal ANALYTICAL CHEMISTRY SKILL ENHANCEMENT COURSE, CBSCBS Publishers & Distributors, 2022
3. B. P. Levitt, Findlay's Practical Physical Chemistry, 9 th Edn, Longman Group Ltd.
4. Vogel's text book of quantitative chemical analysis, Fifth Edition.

24-808-0904 Computational Material Chemistry (4 Credits)

L-T-P 4-0-0 Level: 500

Prerequisites: 24-808-0703 (Approximations and Chemical Bonding) or equivalent

CO	CO Statement	CL
CO1	Appreciate the basics of for quantum chemical calculations for materials	Apply
CO2	Distinguish and apply various methods and basis sets for materials	Apply
CO3	Understand and interpret the band structure of any dimensional materials	Analyse
CO4	Practice and interpret the computed results of various sample materials	Analyse

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	0	2	1	0
CO2	3	2	2	2	2	2
CO3	3	2	2	2	2	2
CO4	3	3	3	3	3	3

Module I (10 hrs)

Basics: Schrodinger's Equation – Periodic Potentials - Bloch Functions – Bonding in Hn systems Reciprocal Space and k Quantum number – Brillouin Zone

Module II (10 hrs)

Band Structures: One-dimensional systems (H_n, N_n, $(H_2)_n$, $[Pt(CN)_4]^{2-}$ systems), Properties of Bands – Band width, Fermi level Interpreting the properties; Structural Distortions; Higher Dimensions; Density of States.

Module III (12 hrs)

Bonds: Basic Electron Partitioning, Energy-resolved Electron and Energy Partitioning, COOP curves and how to interpret these. Electron localization, correlation and exchange energies

Module IV (14 hrs)

Methods and Basis sets: Exchange correlation density functionals. Local density approximation (LDA), density Gradient corrections (GGA). Hybrid and meta–GGA functionals. All electron basis, atomic basis, plane wave basis, Pseudopotential; Normconserving, ultrasoft, PAW

Module V (14 hrs)

Applications Solid state sample problems- Calculating various properties - Structure and energetics, Structural alternative and physical properties; Interpreting the results of material calculations

Recommended Text Books:

1. Hoffmann, R. *Solids and Surfaces*, Wiley-VCH, NY, 1988
2. Cramer, C. J. Essentials of Computational Chemistry, John-Wiley & Sons, 2004.
3. Dronskowski, R. Computational Chemistry of Solid State Materials, Wiley-VCH, 2005
4. Cramer, C. J., "Essentials of Computational Chemistry- Theories and Models", 2nd Edition, Wiley, 2004.
5. Foresman, J. and Frisch, A.," Exploring chemistry with electronic structure methods", GuassianInc, 2000.
6. Jensen, F., "Introduction to Computational Chemistry", 3rdEdition, Wiley, 2017.
7. Leach, A. R., "Molecular Modeling – Principles and Applications", Addison Wesley Longman, 2001
8. Young, D., "Computational Chemistry – A Practical Guide", Wiley, 2001

24-808-0905 Advanced Organic Chemistry II (4 Credits)

L-T-P 4-0-0 Level: 500
Prerequisites: 24-808-0806 or equivalent

CO	CO Statement	CL
CO1	Apply organocatalysts for various organic synthesis	Apply
CO2	Design and synthesis suitable heterogeneous catalysts for various synthetic applications.	Apply
CO3	Understand biorthogonal chemistry and its applications	Understand
CO4	Design and construct suitable polymers with the required properties for different applications.	Apply
CO5	To design and synthesise functional organic materials for specific applications.	Apply

CO No	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	1	2	3	1	2
CO2	1	1	2	3	1	2
CO3	1	1	2	2	1	2
CO4	1	1	2	2	2	2
CO5	1	1	2	2	2	2

Module I(10 hrs)

Organocatalysis: Introduction to organo-catalyzed reactions, amine, iminium, enamine and carbene-based catalysis reactions. Organocatalysis for asymmetric synthesis.

Module II (12 hrs)
Heterogeneous catalysis: introduction, immobilization and solid supports, metal catalysts (single atoms and nanoclusters), organometallic compounds, magnetically active heterogeneous catalysts**.**

Module III (12 hrs)
Introduction to bioorthogonal chemistry: concept, various ligation strategies *viz.*, 1,3-dipolar cycloaddition of azides with cyclooctynes and nitrones with cyclooctynes; oxime/hydrazone formation from aldehydes and ketones, the tetrazine ligation, the isocyanide-based click reaction, and the quadricyclane ligation.

Module IV (13 hrs)
Polymers for advanced technologies: Liquid-crystalline and high-performance polymers, functional polymers, Polymers for drug release and drug carrier systems, Polymeric gels and networks.
Synthesis and applications of conducting polymers: PPVs, polyaniline (PANI) and polythiophene, polycarbazole, polyacetylene-synthesis and applications (sensor and LED). Polymers in solar cell application

Module V (13 hrs)

Functional organic materials: Organic materials for photovoltaic application. Organic electronic luminescent materials. Synthesis of porphyrins and their opto-electrochemical properties.
Introduction to nonlinear optics, molecules for NLO and imaging. Organic molecular switches.
Design, synthesis and functions of Metal-Organic Framework (MOF) and Covalent Organic Framework (COF).

Recommended Text Books

1. L. Albrecht, A. Albrecht, L. Dell'Amico, Asymmetric Organocatalysis: New Strategies, Catalysts, and Opportunities, Wiley-VCH, 2022.
2. MacMillan, D. The Advent and Development of Organocatalysis, Nature, 2008, 455, 304–308.
3. W. Y. Teoh, A. Urakawa, Y. H. Ng, P. Sit, Heterogeneous Catalysts: Advanced Design, Characterization and Applications, WILEY-VCH GmbH, 2021.
4. F. Zaera, Molecular Approaches to Heterogeneous Catalysis, 2021, 214179.
5. Scinto, S. L., Bilodeau, D. A., Hincapie, R. *et al*. Bioorthogonal Chemistry. Nat. Rev. Methods Primers 1, 30 2021.
6. R. E. Bird, S. A. Lemmel, X. Yu, Q. A. Zhou, Bioconjugate Chemistry, 2021, 32, 2457-2479.
7. J. R. Reynolds, B. C. Thompson, T. A. Skotheim, Conjugated Polymers, Perspective, Theory, and New Materials, 4th ed., 2019, Taylor & Francis Group.
8. W. Hou, Y. Xiao, G. Han, J.-Y. Lin, The Applications of Polymers in Solar Cells: A Review. Polymers 2019, 11, 143.
9. V. F. Yusuf, N. I. Malek, S. K. Kailasa, Review on Metal–Organic Framework Classification, Synthetic Approaches, and Influencing Factors: Applications in Energy, Drug Delivery, and Wastewater Treatment, ACS Omega, 2022, 7, 44507-44531.
10. T. J. J. Müller and Uwe H. F. Bunz, Functional Organic Materials- Syntheses, Strategies and Applications, WILEY-VCH, 2007.
11. M. S. Lohse, T. Bein, Covalent Organic Frameworks: Structures, Synthesis, and Applications, Advanced Functional Materials, 2018, 22, 1705553.
12. Introduction to Organic Electronic and Optoelectronic Materials and Devices by Sam-Shajing Sun, Larry R. Dalton, CRC Press, 2008.
13. Organic Optoelectronics by Wenping Hu, John Wiley and Sons, 2013.
14. Organic Electronics Materials and Devices by S. Ogawa, Springer, 2015.
15. A Journey Through the World of Molecular Machines by C. Davis, Create Space, 2010.
16. Molecular Machines and Motors: Recent Advances and Perspectives by A. Credi, S. Silvi and M. Venturi, Topics in Current Chemistry (Springer), 354, 2014.

24-808-1001 Major Project (20 Credits)

The students shall carry out research project in the Department/reputed research laboratory for the entire semester. The students shall submit a project report on the research work carried out.

The students will have to present the results of the research project in a seminar and appear for a comprehensive viva-voce. A course viva will also be conducted along with project evaluation.

24-808-1002 MOOC Course (4 Credits)

Department council will approve a list of MOOC courses to be taken by students. The students can take a course 4 credits or two courses of two credits. The students can take the course during previous semester and credits can be added to the grades of tenth semester.

Syllabus

Five-Year Integrated M.Sc. Major in Biological Sciences

Cochin University of Science and Technology (CUSAT)

w.e.f. June 2024

Program Outcomes: Integrated M.Sc.

PO1: Demonstrate a comprehensive understanding of fundamental principles and concepts in basic sciences.

PO2: Analyse, evaluate, and synthesize complex scientific information and data using appropriate methods and techniques.

PO3: Apply scientific reasoning and critical thinking adeptly to recognize, assess, and resolve problems encountered in various scientific contexts.

PO4: Utilize computational power, programming languages, and modern technologies proficiently to address scientific challenges, effectively integrating technological solutions into problem-solving processes.

PO5: Communicate scientific information effectively and demonstrate proficiency in the use of modern scientific tools and technologies for experimentation, data collection, analysis, and interpretation.

PO6: Adhere to ethical principles and practices in the conduct of scientific research and professional activities, and work collaboratively with others.

PO7: Engage in lifelong learning and professional development to enhance the knowledge and skills in basic sciences.

Program-Specific Outcomes (PSOs)

After the successful completion of the Biology program, the students are expected to

PSO1. Demonstrate an in-depth understanding of fundamental principles that underlie the field of Biology (Animal Science, Plant Science, Microbiology, Biochemistry, Molecular and Cell Biology, Genetics and Genetic Engineering, Immunology, Biotechnology, Computational Biology and Research Methodology).

PSO2. Implement the concept of science and technology to foster the traditional and modern techniques for solving the complex problems in any branches of biology.

PSO3.Show proficiency in performing various basic and advanced laboratory techniques employed in Biology in academia and industries.

PSO4. Design and conduct biological experiments, analyse and interpret experimental data and perform troubleshooting if necessary.

PSO5. Identify a research problem using literature survey, formulate hypothesis, develop a research plan, execute the research plan, write the project report and communicate effectively through written, oral and visual methods.

PSO6. Develop analytical thinking and problem-solving abilities, enabling them to gain skilful jobs in industries and research labs.

PSO7. Develop high thinking and entrepreneurship skills of various ventures in Biology using plant /animal/microbial resources, biological techniques and marketing of bioproducts.

PSO8. Communicate effectively, work in teams and lead in academic and non-academic institutions.

Integrated MSc Biological Sciences Scheme (2024 Admission onwards)

Semester	Number of courses offered by the department						
	Major 4 credits	**Minor 4 credits**	**MDC 3 credits**	**AEC 3 credits**	**SEC 3 credits**	**VAC 3 credits**	**Total credits**
I	1	2	1	2*			21
II	1	2	1	2*			21
III	1	2	1			2*	21
IV	4				1	1*	22
V	5				1		23
VI	5 Courses. Instead of one course with 4 credits, a student may do one/two online courses to acquire 4 credits				1		23
		Internship**					2
Total credits/courses	68 (17) DSC 60 (15) DSE 08 (04)	24 (6)	9 (3)	12 (4)	9 (3)	9 (3)	133
*Courses offered by the Centre for Integrated Studies, CUSAT **Not counted as a course Exit with BSc in Biological Sciences (Total credits = 133)							
VII	5 Courses + seminar/open ended labs/online course (2 credits)						22

VIII	2 Courses + seminar/open ended labs/online (2 credits) + Project (12 credits) Or 4 Major Courses + Mini project (4 credits) + seminar/open ended labs/online course (2 credits)						22
Total credits/courses	Hon. (Research): 112 (26 + Project) Hon. : 112 (28 + Mini Project)	24 (6)	9 (3)	12 (4)	9 (3)	9 (3)	177
Exit with BSc (Honours with Research) in Biological Sciences (Total credits = 177) Exit with BSc (Honours) in Biological Sciences (Total credits = 177)							
IX	5 Courses + online (2 credit**)						20-24
X	Major project + online (2 credit**)						20-24
Total credits	156	24 (6)	9 (3)	12 (4)	9 (3)	9 (3)	221
** Instead of taking two online courses worth 2 credits each, a student can opt for one online course worth 4 credits in the ninth/tenth semester. In such cases, the credits earned in that semester will be 24, and in the other semester, they will be 20. Exit with MSc in Biological Sciences (Total credits = 221)							

MDC: Multi-Disciplinary Courses
AEC: Ability Enhancement Courses
SEC: Skill enhancement Courses
VAC: Value Added Courses

Academic pathways offered by the Department of Biotechnology

Biological Sciences- Major:

3-year UG Program: To earn a Major in Biological Sciences, a 3-year UG Program, a student must complete a minimum of 68 credits in Biological Sciences, out of which 60 credits shall be from DSC courses and 8 credits from DSE courses.

4-year UG Program (Honours): To earn a Biological Sciences Major in a 4-year UG Program (Honours), a student must complete a minimum of 112 credits in Biological Sciences, out of which 96 credits shall be from DSC courses and 16 credits from DSE courses.

4-year UG Program (Honours with Research): To earn a Biological Sciences Major in a 4-year UG Program (Honours with Research), a student must complete a minimum of 112 credits in Biological Sciences, out of which 92 credits shall be from DSC courses and 8 credits from DSE courses and 12 credits from a research project.

Biological Sciences Minor:

3-year UG Program: To earn a Minor in Biological Sciences in a 3-year UG Program, a student must complete a minimum of 27 credits in Biological Sciences, out of which 24 credits shall be from DSC courses and 03 credits from an SEC elective.

4-year UG Program: To earn a Minor in Biological Sciences in a 4-year UG Program, a student must complete a minimum of 35 credits in Biological Sciences, out of which 24 credits shall be from DSC courses and 3 credits from an SEC elective 8 credits from DSE courses.

Discipline mention in Biological Sciences:

To earn a Discipline mention in Biological Sciences in a UG Program (3 or 4 years), a student must complete a minimum of 12 credits in Biological Sciences from DSC courses.

Structure and Scheme of the Course

SEMESTER I

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811-0101	Fundamentals of Life	100	Biological Sciences Major -DSC, Biological Sciences Minor-DSC, Biological Sciences Disci-DSE	3-0-2	50	50	100	4
24-811-0102	Introduction to Animal & Plant Biology	100	Biological Sciences Minor-DSC, Biological Sciences Disci-DSE	4-0-0	50	50	100	4
24-811- 0103	Mysteries of Biology	100	MDC	3-0-0	50	50	100	3
Semester credits	**21 (AEC:6; MDC:3; MAJOR PATHWAY: 4; MINOR PATHWAY: 8)**							**Cumulative credits- 21**

L: Lecture, T: Tutorial, P: Practicum

Biological Sciences Major-DSC: Core course for students Majoring in Biological Sciences.

Biological Sciences Minor-DSC: Core course for students Minoring in Biological Sciences.

Biological Sciences Disc-DSC: Core course for students who choose discipline mention in Biological Sciences.

Biological Sciences -MDC: Multidisciplinary elective course offered to students whose Major or Minor pathways are different from Biological Sciences.

AEC: Ability Enhancement Course (Languages).

MDC: Multidisciplinary Course

CE: Continuous Evaluation

ESE: End Semester Examination

SEMESTER II

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811-0201	Biomolecules	100	Biological Sciences Major - DSC, Biological Sciences Minor- DSC, Biological Sciences Disci- DSE	3-0-2	50	50	100	4
24-811-0202	General Microbiology	100	Biological Sciences Minor- DSC, Biological Sciences Disci- DSE	4-0-0	50	50	100	4
24-811-0203	Biophysical Chemistry	100	MDC	3-0-0	50	50	100	3
Semester credits	**21 (AEC:6; MDC:3; MAJOR PATHWAY: 4; MINOR PATHWAY: 8)**							**Cumulative credits- 42**

SEMESTER III

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811-0301	Genetics & Molecular Biology	200	Biological Sciences Major - DSC, Biological Sciences Minor- DSC, Biological Sciences Disci- DSE	3-0-2	50	50	100	4
24-811-0302	Ecology & Environmental Sciences	200	Biological Sciences Minor- DSC, Biological Sciences Disci- DSE	4-0-0	50	50	100	4
24-811-0303	Human Diseases & Healthcare management	200	MDC	3-0-0	50	50	100	3
Semester credits	**21 (VAC:6; MDC:3; MAJOR PATHWAY: 4; MINOR PATHWAY: 8)**							**Cumulative credits- 63**

SEMESTER IV

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811-0401	Introduction to Biotechnology	200	Biological Sciences Major -DSC	4-0-0	50	50	100	4
24-811-0402	Basic principles of metabolism	200	Biological Sciences Major -DSC	4-0-0	50	50	100	4
24-811-0403	Essential Cell Biology	200	Biological Sciences Major -DSC	4-0-0	50	50	100	4
24-811-0404	Cell Biology & Metabolism Lab	200	Biological Sciences Major -DSC	0-0-8	100	-	100	4
24-811-0405	Scientific Writing and Communication in Biology	200	Biological Sciences Major SEC, Biological Sciences Minor-DSC	3-0-0	50	50	100	3
Semester credits	**22 (VAC:3; SEC:3; MAJOR PATHWAY: 16)**							**Cumulative credits- 85**

SEMESTER V

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811- 0501	Plant Diversity-I	300	Biological Sciences Major -DSC	4-0-0	50	50	100	4
24-811- 0502	Plant Diversity-II	300	Biological Sciences -DSC	4-0-0	50	50	100	4
24-811- 0503	Non-chordates	300	Biological Sciences Major -DSC	4-0-0	50	50	100	4
24-811- 0504	Chordates	300	Biological Sciences Major -DSC	4-0-0	50	50	100	4
24-811- 0505	Animal & Plant Lab	300	Biological Sciences Major -DSC	0-0-8	100	-	100	4
24-811- 0506	Introduction to Cell culture techniques	200	Biological Sciences Major -SEC, Biological Sciences Minor-DSC	3-0-0	50	50	100	3
Semester credits	**23 (SEC:3; MAJOR PATHWAY: 20)**							**Cumulative credits- 108**

SEMESTER VI

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811- 0601	Evolution & Developmental Biology	300	Biological Sciences Major -DSC	4-0-0	50	50	100	4
24-811- 0602	Parasitology & Immunology	300	Biological Sciences -DSC	4-0-0	50	50	100	4
24-811- 0603	Parasitology & Immunology Lab	300	Biological Sciences Major -DSC	0-0-8	100	-	100	4
24-811-060X	Elective I	300	Biological Sciences Major -DSE Biological Sciences Minor -DSC Biological Sciences Disci-DSC	4-0-0	50	50	100	4
24-811-060X	Elective II	300	Biological Sciences Major -DSE Biological Sciences Minor -DSC Biological Sciences Disci-DSC	4-0-0	50	50	100	4
24-811-0604	Basics skills of Computational Biology	200	Biological Sciences Major -SEC, Biological Sciences Minor-DSC	3-0-0	50	50	100	3
24-811-0605	Internship*							2
Semester credits		**23 (SEC:3; MAJOR PATHWAY: 20)**						**Cumulative credits-133**

List of Electives I
24-811-0605 Plant Physiology and Biochemistry
24-811-0606 Economic Botany
24-811-0607 Medicinal Botany
List of Electives II
24-811-0608 Human Physiology and Endocrinology
24-811-0609 Economic Zoology
24-811-0610 Animal Forms and Functions

Internship
Students have to complete an internship of 2 credits (60 Hours of work) before the beginning of Semester VII
*internship should be pre-acquired in the 5th Semester
Exit with 3-year UG Degree OR continue to the 4th year.

Semester VII

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811-0701	Biochemistry	300	Biological Sciences Major -DSC/ Biological Sciences Minor- DSE	4-0-0	50	50	100	4
24-811-0702	Cell Signalling and Communication	400	Biological Sciences -DSC	4-0-0	50	50	100	4
24-811-0703	Advanced Microbiology	400	Biological Sciences Major -DSC	4-0-0	100	-	100	4
24-811-0704	Molecular Biology	400	Biological Sciences Major -DSC	4-0-0	50	50	100	4
24-811-0705	Advanced Biology Lab	400	Biological Sciences Major -DSC	0-0-8	50	50	100	4
24-811-0706	Open-ended Lab	400	Biological Sciences Major -SEC	0-0-4	100	-	100	2
Semester credits	**22 (Major Pathway: 22)**							**Cumulative credits- 155**

SEMESTER VIII
HONS WITH RESEARCH

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811-0801	MOOC1	300	Biological Sciences Major/Minor -DSE	4-0-0	-	100	100	4
24-811-0802	MOOC2	400	Biological Sciences Major -DSE	4-0-0	-	100	100	4
24-811-0803	Project	400	Biological Sciences Major -DSC	0-0-24	200	200	400	12
24-811-0804	Review Writing and Seminar	400	Biological Sciences Major -DSC	0-2-0	100	-	100	2
Semester credits	**22 (Major Pathway: 22)**							**Cumulative credits- 177**

SEMESTER VIII
HONS

Course Code	Course Name	Level	The course can be taken towards obtaining credits for:	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811-0801	Cellular Metabolism	300	Biological Sciences Major -DSC/ Biological Sciences Minor- DSE	3-0-2	50	50	100	4
24-811-0802	Biostatistics & Bioinformatics	400	Biological Sciences Major -DSC	3-0-2	50	50	100	4
24-811-0803	Mini Project	400	Biological Sciences Major -DSC	0-0-8	100	-	100	4
24-811-080X	Elective III	400	Biological Sciences Major -DSE Biological Sciences Minor -DSC Biological Sciences Disci-DSC	4-0-0	50	50	100	4
24-811-080X	Elective IV	400	Biological Sciences Major -DSE Biological Sciences Minor -DSC Biological Sciences Disci-DSC	4-0-0	50	50	100	4
24-811-0804	Critical Analysis of Classical Papers	400	Biological Sciences Major -DSC, Biological Sciences Minor DSC	2-0-0	100	-	100	2
Semester credits	**22 (Major Pathway: 22)**							**Cumulative credits- 177**

List of Electives III

24-811-0805- Analytical Techniques
24-811-0806- Cancer Biology
24-811-0807- Neurobiology

List of Electives IV

24-811-0808- Plant Microbe Interactions
24-811-0809-Biofuels and Bioenergy
24-811-0810- Bioprocessing Methods and Techniques

Exit with 4-year UG Degree OR continue to the 5th year.

SEMESTER IX

Course Code	Course Name	Level	The course can be taken towards obtaining credits for	L-T-P	Marks Distribution			
					CE	ESE	Total	Credit
24-811-0901	Immunology	500	Biological Sciences Major - DSC	4-0-0	50	50	100	4
24-811-0902	Genetic Engineering	500	Biological Sciences Major - DSC	4-0-0	50	50	100	4
24-811-090X	Elective V	500	Biological Sciences Major - DSE Biological Sciences Minor - DSC Biological Sciences Disci-DSC	4-0-0	50	50	100	4
24-811-090X	Elective VI	500	Biological Sciences Major - DSE Biological Sciences Minor - DSC Biological Sciences Disci-DSC	4-0-0	50	50	100	4
24-811-0903	Immunology & Genetic Engineering lab	500	Biological Sciences Major - DSC	0-0-8	100	-	100	4
24-811-0904	Online course	500	Biological Sciences Major - DSC, Biological Sciences Minor-DSC	2-0-0 OR 4-0-0	-	100	100	2 or 4
Semester credits	**20-24 (Core: 12; Elective 10)**							**Cumulative credits-199**

List of Electives V
24-811-0905- NGS and Data Analysis
24-811-0906- Environmental Microbiology
24-811-0907- Microbiome
24-811-0908- Molecular Virology

List of Electives VI
24-811-0909- Environmental Biotechnology
24-811-0910- Plant Biotechnology
24-811-0911- Stem Cell and Regenerative Medicine
24-811-0912- Biopharmaceuticals
24-811-0913- Gene Silencing and Genome Editing

SEMESTER X

Course Code	Course Name	Level	The course can be taken towards obtaining credits for	L-T-P	Marks Distribution			
					CE	**ESE**	**Total**	**Credit**
24-811-1001	Major Project	600	Biological Sciences Major-DSC	0-0-40	600	-	600	20
24-811-1002	Online course** (if taken in IX for 4C then No need to take here)	500	Biological Sciences Major-DSE	2-0-0	-	100	100	2
Semester credits	**20-24 (Core: 20; Elective:2)**							**Cumulative credits-221**

**Instead of taking the online course worth 2 credits, a student has the option to select one online course worth 4 credits in the ninth/tenth semester. In such cases, the credits earned in that semester will total 24. Consequently, they won't need to enroll in the MOOC course in the other semester, and the maximum credits for that semester will be 20.

SEMESTER I

24-811-0101. FUNDAMENTALS OF LIFE (4C; 3L+0T+2P) (Academic Level 100)

Course description: The course covers the studies of living creatures, from the tiny and simple through to the complexities of plants and animals, ending with a basic understanding of ecology and the study of population dynamism. Different scopes of biology will also be conveyed to the students.

Course outcomes: After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Explain the biological processes common to life	Understand
C.O. 2: Compare fundamental differences in the forms and how they may differ	Analyse
C.O. 3: Comprehend and explain how present-day organisms may have arisen	Understand
C.O. 4: Interpret how different life forms, including humans, interact with each other and with the physical, chemical and biological world around them.	Analyse
C.O. 5: Use the knowledge gained through scopes of biology for higher studies and furthering careers in biology.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	-	2	-				
CO2	2	-	-	-				
CO3	3	-	-	-		2		
CO4	2	-	2	-				
CO5	2	-	-	-			1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Introduction to cell: Cell theory, Cell and its components: nucleus, mitochondria, chloroplast, Golgi apparatus, ribosomes, vacuoles; types of cells, the concept of tissues

MODULE II: Biomolecules of life: Water as a biological solvent, carbohydrate, nucleic acid, amino acids, proteins, lipids, enzymes, vitamins, and minerals.

MODULE III: Biodiversity: concept, values and types of biodiversity. Analysing and documenting biodiversity. Maintenance of ecological diversity, Biodiversity hotspots in India.

MODULE IV: Ecology and Conservation: Concepts and elements of Biotic and Abiotic environment; Interaction between biotic and abiotic environment; Ecosystem- concept and components, Community-structure and dynamics; Biome- grassland, tundra, forest, deserts, salt

& freshwater ecosystem; Biodiversity and Conservation; Impact of climate change on biodiversity.

MODULE V: Principles of Developmental Biology & Evolution: Basic concepts in developmental biology regarding plants and animals, and their biological significance Introduction to evolution: History, Types, Theories, and evidence of Evolution.

Suggested Practical

1. Familiarizing with microscopes and their application.
2. Microscopic examination and identification of unicellular and multicellular life forms: Monerans: Euglena, Paramecium, Amoebae, Chlamydomonas, Chlorella, Diatoms.
3. Microscopic observation of bacteria and fungi
4. Volvox as a model of evolution- (Cellular level- single cell to the multicellular organization)

REFERENCES

1. Reece, J. B., & Campbell, N. A. (2011). Campbell Biology. Boston, Benjamin Cummings / Pearson.
2. Manuel C Molles, Ecology: Concepts and Applications McGraw Hill 7th Edition 2014
3. Douglas J Futuyma, Evolution Oxford University Press 3rd Edition 2013
4. Barton et al., Evolution Cold Spring Harbor Laboratory Press 1st Edition 2007
5. Stephen C. Stearns and Rolf F. Hoekstra, Evolution: An Introduction Oxford University Press 1st Edition 2000
6. Nicholas J. Gotelli, A primer of Ecology Oxford University Press, 4th Edition 20086. Begon et al., Ecology: From Individuals to Ecosystem Wiley-Blackwell, 4th Edition 2005
7. Instant notes on ecology by A. Mackenzie, A.S. Ball, S.R. Virdee, 2nd edition- 2020

24-811-0102 INTRODUCTION TO ANIMAL & PLANT BIOLOGY (4C; 4L+0T+0P) (Academic Level 100)

Course description: This course provides a foundation for understanding the fundamental principles of life focusing on plants and animals. Through lectures, discussions, and laboratory exercises, we will explore the diversity, structure, function, and inter-dependence of these two kingdoms within the biological world.

Course Outcomes: After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Understand the vast diversity of plants and animals	Understand
C.O. 2: Comprehend the basic structure and function of animal plant cells and reproduction	Understand
C.O. 3: Comprehend the basic structure and function of animal cells and tissues	Understand
C.O. 4: Understand the basic concepts of nutrition	Understand

C.O.5: Analyse the inter-relationships between plants and animals within ecosystems.	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2							
CO3	2							
CO4	2							
CO5	2					2		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I-Introduction: Characteristics of life, The scientific method and biological inquiry, Classification of living organisms (including major plant and animal groups)

MODULE II- Plant cell structure and function (including photosynthesis); Plant tissues, organs, and organ systems, Transport in plants (water and nutrients), Plant reproduction (sexual and asexual)

MODULE III- Animal structure and function: Animal cell structure and function, Animal tissues, organs, and organ systems (digestive, respiratory, circulatory, excretory, nervous, endocrine, reproductive), Animal movement and behaviour, Sensory reception

MODULE IV- Nutrition and Gas Exchange: Autotrophs vs. heterotrophs, Types of nutrition in plants and animals, Digestion and absorption in animals, Respiration in plants and animals

MODULE V- Interdependence and the Environment: Symbiotic relationships between plants and animals, Importance of plants and animals in ecosystems, Threats to biodiversity and conservation efforts

REFERENCES

1. Burgess, J. (1985). Introduction to Plant Cell Development. United Kingdom: Cambridge University Press.
2. Pandey, B. P. (2001). College Botany - Volume I. India: S. Chand Limited.
3. Agarwal, V. K. (2022). Zoology for Degree Students (For B.Sc. Hons. 4th Semester, As per CBCS). India: S Chand & Company Limited.
4. Campbell, P. N. (2013). The Structure and Function of Animal Cell Components: An Introductory Text. United Kingdom: Elsevier Science.
5. Yadav, P. R. (2006). Biotechnology of Animal Tissues. India: Discovery Publishing House Pvt. Limited.
6. Schulze, E., Beck, E., Müller-Hohenstein, K. (2005). Plant ecology. Germany: Springer.
7. Jain, V. K. (2000). Fundamental Of Plant Physiology. India: S. Chand Limited.
8. Animal Physiology. (2000). India: S. Chand, Limited.

24-811-0103 MYSTERIES OF BIOLOGY (3C; 3L+0T+0P) (Academic Level 100)

Course Description:
This course delves into captivating and intriguing aspects of the biological sciences, exploring fascinating phenomena, extraordinary adaptations, and curious behaviours exhibited by organisms across various taxa. Through a combination of lectures, discussions, readings, and hands-on activities, students will develop a deeper appreciation for the wonders of the natural world and gain insight into the scientific processes that unravel its mysteries.

Course Outcomes: After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Explore the captivating topics in biology that ignite curiosity and inspire further study.	Apply
C.O. 2: Develop critical thinking skills through the analysis of complex biological phenomena.	Analyse
C.O. 3: Appreciate the diversity of life and the interconnectedness of biological systems.	Analyse
C.O. 4: Develop independent inquiry and research interest in fascinating biological topics.	Analyse
C.O. 5: Apply the knowledge gained for higher studies and furthering careering in biology and biological research.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2							2	
CO3	2							
CO4	2				1			
CO5	2						1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module I- Introduction to Fascinations of Biology-Overview of the course objectives and structure**;** Importance of curiosity and wonder in biological sciences**;** Bioluminescence: Mechanisms and ecological significance of bioluminescence**;** Case studies of bioluminescent organisms

Module II- Extreme Environments- Adaptations of extremophiles to extreme conditions; Exploration of extreme environments on Earth and beyond; Cryptic Coloration and Mimicry: Camouflage, cryptic coloration, and mimicry in the animal kingdom; Examples of mimicry in insects, amphibians, and other organisms

Module III- Behavioural Ecology: Evolutionary drivers of animal behaviour; Case studies of complex behaviours in various species; Plant Communication: Signalling and communication mechanisms in plants; Inter-plant communication and defence strategies; **Unusual Reproductive Strategies**: Unique reproductive strategies in plants and animals; Ecological and evolutionary implications of different reproductive strategies

Module IV- Genetic Engineering and Synthetic Biology: Applications and ethical considerations of genetic engineering; Cutting-edge developments in synthetic biology

Neuroscience Mysteries: Fascinating phenomena in neuroscience; Current research and theories addressing neuroscientific mysteries

Module V- Evolutionary Arms Race: Coevolutionary interactions between species; Evolutionary adaptations driven by competition and conflict; Biodiversity Hotspots: Importance of biodiversity hotspots for conservation; Threats to biodiversity and efforts to preserve it; **Emerging Infectious Diseases**: Impact of emerging infectious diseases on human health and ecosystems; Factors contributing to disease emergence and spread

REFERENCES

1. Campbell, P. N. (2013). The Structure and Function of Animal Cell Components: An Introductory Text. United Kingdom: Elsevier Science.
2. Yadav, P. R. (2006). Biotechnology of Animal Tissues. India: Discovery Publishing House Pvt. Limited.
3. Schulze, E., Beck, E., Müller-Hohenstein, K. (2005). Plant ecology. Germany: Springer.
4. Jain, V. K. (2000). Fundamental Of Plant Physiology. India: S. Chand Limited.
5. Animal Physiology. (2000). India: S. Chand, Limited.
6. Smith and Smith (2014) Ecology 9th edition. Pearson Education
7. Desmond S. T. Nicholl (2023) An Introduction to Genetic Engineering

SEMESTER II

SEMESTER II

24-811-0201- BIOMOLECULES (4C; 3L+0T+2P) (Academic Level 100)

Course description: The program is designed to enable a student to acquire sound knowledge of biochemistry and its practical applicability. The course will encourage the students to join the industry or to prepare them for higher studies including research. The syllabus is based on a basic and applied approach to ensure that students develop problem-solving skills, laboratory skills, chemistry communication skills, team skills as well as ethics.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Describe the significance of biomolecules	Understand
C.O. 2: Differentiate the biomolecules (proteins, lipids, nucleic acids, and carbohydrates) based on their structural basis	Analyse
C.O. 3: Quantify various biomolecules.	Analyse
C.O. 4: Employ chromatographic techniques to separate various biomolecules.	Apply
C.O. 5: Apply proper procedures and regulations in handling and disposal of chemicals.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2	2	1					
CO3	2	2	2					
CO4	2	2	1	1				
CO5	2		1	1				

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: A brief history of biochemistry, Basic chemistry- Elements, Functional groups, pH, Mole concept, Bonding and chirality, non-covalent interactions, Water, interactions in aqueous systems, Molarity, normality, Ionization state of biomolecules, Laws of thermodynamics, Gibbs free energy, and maintenance of equilibrium.

MODULE II: Carbohydrates: Structure, chemical & biological properties and functions. Monosaccharides- Ribose, Glucose and fructose. Oligosaccharides -Sucrose, maltose, lactose, Polysaccharides- Glycogen, cellulose and starch. Glycoproteins, proteoglycans and glycolipids. Hetero-polysaccharides, Carbohydrates as informational molecules- the sugar code.

MODULE III: Nucleic Acids: Nucleotides, Nucleic Acid composition, a historical perspective leading up to the proposition of DNA double-helical structure; the difference in RNA and DNA structure and their importance in the evolution of DNA as the genetic material. Lipids & Fats: Storage lipids, Structural lipids in membranes, Lipoproteins. Lipids as signals, cofactors and pigment, biological functions of lipids. Vitamins and Minerals: General accounts and biological functions.

MODULE IV: Proteins: structural and functional group properties; pH and properties of amino acids, Peptides and covalent structure of proteins; peptide bond, polypeptide, protein structure- secondary, tertiary and quaternary, protein structure & function, Enzymes as Biological Catalysts: General principles of enzyme catalysis, Activation energy and stereospecificity, classification of enzymes; Types of enzymes and their specific functions. Enzyme characterization and Michaelis–Menten kinetics, Regulation and Inhibition of enzyme.

MODULE V: Methods in Biophysical and Biochemical Analysis: Buffers, pH meter, Calorimetry, Spectrophotometry, Centrifugation techniques, Mass spectrometry, Chromatographic techniques, Electrophoretic Techniques.

Suggested practical

1. Preparation of Normal and Molar solutions
2. Preparation of Buffers (Acidic, Neutral and Alkaline Buffers)
3. Verification of Beer Lambert's law
4. Estimation of biomolecules (glucose, protein, lipids and nucleic acid).
5. Separation of biomolecules using paper and TLC
6. Electrophoretic Techniques

REFERENCES

1. Rodney F Boyer, Concepts in Biochemistry. John Wiley & Sons; 3rd Ed (2 December 2005).
2. Thomas Millar, Biochemistry Explained: A Practical Guide to Learning Biochemistry CRC Press; 1 edition (30 May 2002)
3. Lubert Stryer et al., Biochemistry, W. H. Freeman; 6th Edition (14 July 2006)
4. David L Nelson, and Michael M Cox et al., Lehninger principles of biochemistry WH Freeman; 7th ed.2017 edition (1 January 2017)
5. Lehninger. Principles of Biochemistry, Macmillan, U.K.
6. Geoffrey Zubay. Biochemistry. Macmillan Publishing company, New York
7. Sadasivam and Manickam. Biochemical Methods. New Age International Publishers. NewDelhi.
8. David T. Plummer, An Introduction to Practical Biochemistry. Tata McGraw Hill.
9. Nelson, D. L., Lehninger, A. L., & Cox, M. M. (2008). Lehninger principles of biochemistry. Macmillan
10. Tymoczko, J. L., Berg, J. M., &Stryer, L. (2011). Biochemistry: a short course. Macmillan.
11. Voet, D., & Voet, J. G. (2016). Fundamentals of Biochemistry. 5th Edition. Wiley & Sons.

24-811-0202- GENERAL MICROBIOLOGY (4C; 4L+0T+0P) (Academic Level 100)

Course Description:

General Microbiology is an introductory course that explores the fundamental principles of microbiology, focusing on the morphology, physiology, genetics, ecology, and pathogenesis of microorganisms. Students will examine the diversity of microorganisms, including bacteria, viruses, fungi, and protozoa, and their roles in various environments, human health, and biotechnology. Laboratory exercises will complement theoretical concepts, providing hands-on experience in microbiological techniques and experimentation.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1 Understand the basic characteristics and classification of microorganisms and to explore the structure and function of microbial cells	Understand
C.O. 2: Examine microbial growth and metabolism	Analyse
C.O. 3: Investigate the genetics and molecular biology of microorganisms.	Analyse
C.O. 4: Analyse the interactions between microorganisms and their environments and to study the role of microorganisms in human health and disease.	Apply
C.O. 5: To develop proficiency in microbiological techniques and laboratory skills.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2	2	1					
CO3	2	2			1			
CO4	2	1	1	1				
CO5	2	1	2	1	1			

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I Introduction to Microbiology- Definition and scope of microbiology; Historical perspectives; Microbial diversity and classification. **Microbial Cell Structure and Function**- Prokaryotic and eukaryotic cell structure; Cell wall composition and function; Membrane structure and transport mechanisms; Microbial motility and appendages

MODULE II Microbial Growth and Metabolism-Growth requirements and factors affecting growth; Nutritional categories and metabolic pathways; Energy production and ATP synthesis; Microbial fermentation and respiration. **Microbial Genetics**- DNA structure and replication; Gene expression and regulation; Mutation and genetic variation; Horizontal gene transfer

MODULE III Microbial Ecology- Microbial interactions and symbiosis**;** Biogeochemical cycles and microbial roles**;** Microbial communities and ecosystems. **Environmental Microbiology**- Microbial adaptation to extreme environments; Bioremediation and microbial degradation; Microbial contributions to agriculture and industry

MODULE IV Microorganisms and Human Health- Host-microbe interactions**;** Infectious diseases and epidemiology; Immunology and host defence mechanisms**;** Microbial pathogenesis and virulence factors

MODULE V. **Microbiological Techniques**- Aseptic techniques and culture methods; Microscopic examination of microorganisms; Biochemical tests for microbial identification; Molecular techniques and genetic analysis

Suggested Practical

1. Sterile technique and media preparation
2. Microbial isolation and staining techniques
3. Microbial growth kinetics and quantification
4. Identification of unknown microorganisms
5. Molecular biology techniques (PCR, gel electrophoresis, etc.)

REFERENCES

1. Prescott's Microbiology, 10th Edition Authors: Joanne Willey, Linda Sherwood and Christopher J. Woolverton, 2016
2. Microbiology: An Introduction, 13th Edition Authors: Gerard J. Tortora, Berdell R. Funke and Christine L. Case, 2018
3. Microbiology Fundamentals: A Clinical Approach (3rd Edition) Marjorie Kelly Cowan, Heidi Smith, Jennifer Lusk, 2019
4. Ananthanarayan and Paniker's Textbook of Microbiology, (12th Edition) 2022

24-811-0203- BIOPHYSICAL CHEMISTRY (3C; 3L+0T+0P) (Academic Level 100)

Course Description: This course aims to provide an overview of some of the fundamentals of biophysics and biochemistry. The course will discuss advanced topics with an emphasis on structure, function relationships and techniques for probing the structure and dynamics of biological systems.

Course Outcome (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Describe the basic units in biological science	Understand
C.O.2: Discuss the laws of Thermodynamics and biomolecular interactions	Understand
C.O.3: Discuss the biomolecular kinetics and protein chemistry	Understand
C.O. 4: Differentiate the different types of microscopes and their working principles and elucidate different chromatographic techniques.	Analyse
C.O.5: Elucidate the mechanisms of various separation techniques in spectroscopy and their applications	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8

CO1	3							
CO2	2	2						
CO3	2	1						
CO4	2	1	1					
CO5	2	1	1					

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- Introduction to Biophysical Chemistry- Definition and scope of biophysical chemistry**;** Interdisciplinary nature of the field**;** Historical development and key concepts. Introduction to measurements, SI units-standard units for measurement, Basic units, Derived units-volume; Mole concept; Hydrogen ion concentration. -pH. Determination of pH. Dissociation of weak acids (pKa), Buffers of blood plasma, red blood cells and tissue fluids.

MODULE II- Thermodynamics of Biomolecular Systems- Laws of thermodynamics and their application to biological systems; Thermodynamic properties of biomolecules; Gibbs free energy and its role in biochemical reactions. **Biomolecular Interactions-** Properties of covalent molecules- bond length, energy and bond angle. Hydrogen bond, inter-and intra-bio-molecular interactions.

MODULE III- Kinetics of Biomolecular Reactions-Rate laws and reaction mechanisms**;** Enzyme kinetics and catalysis**;** Transition state theory and reaction mechanisms. **Protein Folding and Stability**- Protein folding pathways and energy landscapes; Factors influencing protein stability; Chaperones and protein folding diseases

MODULE IV- Basics of microscopy: principle, working, types (light, electron microscopy) and application of microscopy in life science research; Separation techniques: **Chromatography**- basic principles, types and application; Centrifuge- Basic principle, types and applications.

MODULE V- Electrophoresis- Basic principle, types and applications; Biopolymers-Classification. polymerization process. **Spectroscopy**: Basic principles, Beer-Lamberts law, types and applications, X-ray crystallography and NMR spectroscopy, Radioisotopes-applications in life science

REFERENCE

1. Rodney F Boyer, Concepts in Biochemistry. John Wiley & Sons; 3rd Ed (2 December 2005)
2. Single Molecule Biology. (2009). Netherlands: Elsevier Science
3. McMurry, J. (2013). Fundamentals of General, Organic, and Biological Chemistry. United Kingdom: Pearson.
4. Springer Handbook of Microscopy. (2019). Germany: Springer International Publishing.
5. Roberson, R. W., Chandler, D. E. (2009). Bioimaging: current concepts in light and electron microscopy. United Kingdom: Jones and Bartlett Publishers.
6. Gel Electrophoresis. (1964). United States: Academy.
7. Pavia, D. L., Vyvyan, J. A., Lampman, G. M., Kriz, G. S. (2014). Introduction to Spectroscopy. United States: Cengage Learning.

SEMESTER III

SEMESTER III

24-811-0301- GENETICS AND MOLECULAR BIOLOGY (4C; 3L+0T+2P) (Academic Level 200)

Course Description: This course aims to provide an overview of genetics starting from the work of Mendel to the current understanding of various phenomena like recombination, transposition, sex determination and mutations. The course will help in building sound fundamental knowledge of the principles of genetics, to be used as a stepping stone for higher studies and research in this field. The course also aims to provide students with an introduction of the underlying molecular mechanisms of various biological processes in cells and organisms. The study primarily involves learning about the structure and synthesis of deoxyribose and ribose nucleic acids, the formation of proteins, and the regulation of gene expression. The course aims to develop a basic understanding of molecular biology techniques and their applications.

Course Outcomes: After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Describe the basic principles of inheritance with examples	Understand
C.O.2: Predict the inheritance pattern of heredity based on classical genetics and gene interaction analysis	Analyse
C.O. 3: Differentiate the basic structures of DNA and RNA Discuss the DNA replication machinery in prokaryotes and eukaryotes.	Understand
C.O. 4: Explain the mechanism of the flow of genetic information in prokaryotes and eukaryotes	Analyse
C.O.5: Discuss and apply the knowledge of gene regulation in Molecular biology studies in lab	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	2	1	1					
CO3	2	1	1	1	1			
CO4	2			1	1			
CO5	2	1	1	1	1			1

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I-Mendelian Genetics- Mendelian principles, the concept of traits & alleles, monohybrid and dihybrid crosses, back cross and test cross and Mendel's success, Modified Mendelian ratios; Incomplete dominance, Recessive and Dominant epistasis, Complementary genes, Duplicate gene, Duplicate dominant genes and Inhibitory factor. Multiple Alleles- General accounts. ABO blood group in man. Rh factor. Quantitative characters- quantitative inheritance, polygenic inheritance, cytoplasmic inheritance.

MODULE II -Linkage and crossing over- Linkage and its importance, linkage and independent assortment. Complete and incomplete linkage. Crossing over – a general account, two-point and three-point test crosses. Determination of gene sequence. Interference and coincidence. Mapping of chromosomes (recombination mapping) and complementation analysis. Conjugation, transduction and transformation. Sex determination- Sex chromosomes, the chromosomal basis of sex determination in Drosophila and humans. Pedigree analysis.

MODULE III- Introduction: history, development and scope of molecular biology. DNA as the genetic material, Griffith's experiment, Avery, Mac Leod and Mc Carty, experiment, Hershey & Chase's experiment. Structure of nucleic acids - Watson - Crick model of DNA, DNA replication in prokaryotes and eukaryotes. Semi-conservative method. Replication machinery and mechanism, enzymes involved in DNA replication. Arrangement of DNA in a chromosome- Nucleosome structure. Modification and repair of DNA. Different types of DNA and RNA.

MODULE IV- Gene Expression: One gene-one enzyme hypothesis, one gene-one polypeptide hypothesis, central dogma hypothesis, colinearity of genes and gene products. RNA: structure & types, Genetic code - features and wobble hypothesis. Contributions of Nirenberg and his associates, Khorana and his associates. Transcription of RNAs and post-transcriptional modifications & reverse transcription and PCR. Translation and post-translational modification of proteins

MODULE V- Gene regulation in prokaryotes; operon concept - Lac operon and Trp operon. Regulation of eukaryotic gene expression. Level of control of gene expression, transcriptional factors, regulation of RNA processing, mRNA translation, mRNA degradation & protein degradation control, epigenetics.

Suggested Practical

Genetics

1. Monohybrid cross and Dihybrid cross using Pea plant & Drosophila.
2. Gene interactions
3. Barr body staining from cheek cells
4. Preparation of human karyotype and study of chromosomal aberrations with respect to number, translocation, deletion, etc. from the pictures provided.

Molecular Biology

1. Genomic DNA isolation
2. PCR amplification of DNA (Demo)
3. Electrophoretic separation of Nucleic Acid/Proteins
4. Scoring of bands on RAPD Agarose gel
5. Use of restriction enzymes- Single and double digestion

REFERENCES

1. Alberts, B., Johnson, A., Walter, P., Lewis, J., Raff, M., & Roberts, K. (2008). Molecular cell biology. New York: Garland Science.
2. Lodish, H., Berk, A., Darnell, J. E., Kaiser, C. A., Krieger, M., Scott, M. P. & Matsudaira, P. (2008). Molecular cell biology. Macmillan.
3. Lewin, B., Krebs, J. E., Goldstein, E. S., & Kilpatrick, S. T. (2014). Lewin's Genes XI. Jones & Bartlett Publishers.
5. Hardin, J., Bertoni, G. P., & Kleinsmith, L. J. (2017). Becker's World of the Cell. Pearson Higher Ed.
6. Baker, T. A., Watson, J. D., & Bell, S. P. (2003). Molecular biology of the gene. Benjamin-Cummings Publishing Company.

24-811-0302 ECOLOGY AND ENVIRONMENTAL SCIENCES (4C; 4L+0T+0P) (Academic Level 200)

Course description: This course explores the interconnectedness of living organisms with their environment and the challenges we face in maintaining a healthy planet. Through lectures, discussions, labs, and field trips the students will have a classic experience on the various concepts of ecology and environmental science.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Understanding the basic concepts of ecology and evolution	Understand
C.O. 2: Evaluate the basic components of the ecosystem	Analyse
C.O. 3: Understanding the concepts of population	Understand
C.O. 4: Analyse human impacts on the environment, including pollution, climate change, and habitat loss	Analyse
C.O. 5: Understanding the fundamentals of environmental policies and legislation	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2							
CO3	2							
CO4	2			2			1	
CO5	2				2		1	1

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- Introduction to Ecology and Environmental Science: The science of ecology and environmental science: history, key concepts, and interdisciplinary nature. Levels of ecological organization: populations, communities, ecosystems, biomes, the biosphere. Environmental ethics and sustainability principles.

MODULE II- Abiotic and biotic components of ecosystems, Energy flow through ecosystems: trophic levels, food webs, energy pyramids. Biogeochemical cycles: carbon, nitrogen, phosphorus, water. Ecological succession: primary and secondary succession.

MODULE III- Population characteristics: density, dispersion, growth patterns, Population regulation: density-dependent and density-independent factors. Life history strategies: r- and K-selection. Human population growth and its ecological consequences.

MODULE IV- Environmental pollution: types, sources, and impacts (air, water, soil), Climate change: causes, consequences, and mitigation strategies, Habitat loss and biodiversity decline, Impacts of Environmental pollution, Resource depletion and sustainable use practices.

MODULE V- Environmental policy and legislation, Renewable energy sources and energy conservation, Sustainable resource management practices, Individual actions and collective responsibility for environmental protection.

REFERENCES

1. Townsend, C. R., Begon, M., & Harper, J. L. (2008). *Essentials of ecology* (No. Ed. 3). Blackwell publishing.
2. Begon, M., Howarth, R. W., & Townsend, C. R. (2014). *Essentials of ecology*. John Wiley & Sons.
3. Rana, S. V. S. (2009). Essentials of Ecology and Environmental Science. India: Prentice-Hall Of India Pvt. Limited.
4. Hadjibiros, K. (2013). Ecology and Applied Environmental Science. United Kingdom: CRC Press.
5. Yadav, P. R., Mishra, S. R. (2004). Environmental Ecology. India: Discovery Publishing House.
6. Ecology, Environmental Science & Conservation. (2014). India: S. Chand Pvt. Limited.

24-811-0303- HUMAN DISEASES AND HEALTH CARE MANAGEMENT (3C; 3L+0T+0P) (Academic Level 200)

Course Description: This course will introduce the basic knowledge of various aspects of human diseases and the healthcare industry. It also aims to understand various factors that contribute to the occurrence of diseases and how those diseases may be treated by clinical professionals.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcomes	**Cognitive Level**
C.O. 1: Demonstrate a basic understanding of the mechanism of diseases, diagnosis and treatment	Understand
C.O. 2: Discuss the understanding of the pathophysiology	Understand
C.O. 3: Demonstrate the knowledge of various diseases affecting the organs	Understand
C.O.4: Discuss the importance of genetic disorders and their possible cures	Apply
C.O.5: Discuss the various aspects of public health policy and health care management	Apply

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	2	2						
CO2	2	1						
CO3	2	2			1			
CO4	2	1			1		1	
CO5					1		1	1

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- Epidemiology and Infectious Diseases. Overview of epidemiology, epidemiology tools, history of diseases, quantifying disease in a population, comparing disease rate, outbreaks of disease, epidemiological aspects of infections and chronic diseases of national importance.

MODULE II- Basics of Pathophysiology. Introduction to the basics of pathophysiology, altered cellular and tissue biology, cellular adaptation, atrophy, hypertrophy, hyperplasia, dysplasia, metaplasia, cell injury, immunological & inflammatory injury, manifestations of cellular injury, cell death: apoptosis, necrosis, and autophagy.

MODULE III- Pathophysiology of Organ Dysfunction and Disorders. Diseases of the nervous system, Diseases of the endocrine system, Diseases of the cardiovascular system, Diseases of the reproductive system and sexually transmitted diseases.

MODULE IV- Genetic Disorders: General introduction to human genetics and various genetic disorders, autosomal and X-linked disorders, gene mutation and chromosomal abnormalities, inborn errors of metabolism, pedigree analysis, introduction to cytogenetics and its applications.

MODULE V- Public Health Policy and Health care Management: Overview of public health policy, an overview of WHO and global health policies, an overview of Indian public health policies, Health Care Management Overview of public health care management in India and other countries.

REFERENCES

1. Pathophysiology of Disease: An Introduction to Clinical Medicine 8E. (2018). United Kingdom: McGraw-Hill Education.
2. Marya, R. K. (2006). Pathophysiology. India: CBS Publishers & Distributors.
3. Wright, A., Hastie, N. (2007). Genes and Common Diseases: Genetics in Modern Medicine. United Kingdom: Cambridge University Press.
4. Thompson, E. A. (1986). Pedigree Analysis in Human Genetics. United Kingdom: Johns Hopkins University Press.
5. Pal, G. P. (2009). Medical Genetics. India: A.I.T.B.S. Publishers.
6. Agarwal, V. K. (2009). Genetics. India: S. Chand Limited.
7. Introduction to Health Care Management. (2016). United States: Jones & Bartlett Learning.

SEMESTER IV

SEMESTER IV

24-811-0401- INTRODUCTION TO BIOTECHNOLOGY (4C; 4L+0T+0P) (Academic Level 200)

Course Description: This course is designed to give students both a theoretic background and a working knowledge of instrumentation and techniques employed in a biotechnology lab. Emphasis will be placed on the introduction of foreign DNA into bacterial cells as well as the analysis of nucleic acids and proteins.

Course Outcome (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Explain the different frontiers in Biotechnology	Understand
C.O. 2: Explain the mechanisms of molecular cloning	Understand
C.O. 3: Discuss various transformation techniques and generation of genetically modified organisms	Apply
C.O. 4: Elucidate the mechanism of data mining and data processing	Apply
C.O.5: : Learn and apply the knowledge of IPR and patenting in Biotechnology	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							2
CO2	1	1	1	1				
CO3	2	2	1	1				
CO4	2			1	1			
CO5	2				1		1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- Introduction-Major areas of Biotechnology, revolutionary discoveries and their applications: blue biotechnology (marine) White biotechnology (industry), yellow biotechnology (food production), grey biotechnology (bioremediation and environmental improvement), brown biotechnology (desert), gold biotechnology (bioinformatics, nanotechnology and computer science), violet biotechnology (legal, ethical and philosophical issues), dark biotechnology (bioweapons and warfare).

MODULE II- Molecular techniques in gene manipulation: Restriction enzymes, cloning vectors and expression vectors, steps involved in cloning, transformation techniques. Cloning and expression vectors. Restriction enzymes- nomenclature, types and mechanisms.

MODULE III- Transformation techniques- gene gun, calcium chloride method and electroporation. Genomic and cDNA library construction and their applications **Genetically modified organisms**: Applications and status, Production of genetically modified plants and animals with examples. Selection of transgenics using various techniques

MODULE IV- General bioinformatics: Different types of file formats, biological data, and databases- general classification. Text-based and sequence-based search engines, Sequence alignment techniques. Introduction to different operating systems.

MODULE V- Intellectual property rights: Introduction, commercialisation, patent laws, copyrights, royalty, plagiarisms, citations, acknowledgements. Geographical indications, protection of plant varieties.

REFERENCES

1. Basic Biotechnology. (2006). United Kingdom: Cambridge University Press.
2. Dubey, R. C. (1993). A Textbook of Biotechnology. India: S. Chand Limited.
3. Loroch, V., Renneberg, R. (2016). Biotechnology for Beginners. Germany: Elsevier Science.
4. Pazdernik, N., Clark, D. P. (2012). Molecular Biology. Netherlands: Elsevier Science.
5. Ploegh, H., Amon, A., Berk, A., Kaiser, C. A., Bretscher, A., Krieger, M., Lodish, H., Martin, K. C. (2016). Molecular Cell Biology. United Kingdom: W. H. Freeman.
6. Parashar, S., Goel, D. (2013). IPR, Biosafety and Bioethics. India: Pearson Education India.
7. The Role of Intellectual Property Rights in Agriculture and Allied Sciences. (2018). Canada: Apple Academic Press.
8. Xiong, J. (2006). Essential bioinformatics. Spain: Cambridge University Press.
9. Dubey, R. C. (2014). Advanced Biotechnology. India: S. Chand Limited.

24-811-0402- BASIC PRINCIPLES OF METABOLISM (4C; 4L+0T+0P)
(Academic Level 200)

Course Description: This course will provide a basic understanding of metabolism by studying its major pathways, regulation, and molecular components. It will cover the various aspects of metabolism and biochemistry. This course is designed to teach students with basics of the metabolism of various biomolecules.

Course Outcome (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Explain the different aspects of thermodynamics and bioenergetics and explain why ATP is the energy currency of the cell	Apply
C.O. 2: Explain the mechanisms of metabolism of carbohydrates	Understand
C.O. 3: Explain the mechanisms of metabolism of lipids	Understand
C.O. 4: Explain the mechanisms of metabolism of amino acids	Understand
C.O.5: Explain the mechanisms of metabolism of nucleic acids	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	1						
CO2	2					1		
CO3	2					1		
CO4	2					1		
CO5	2					1		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- Overview of thermodynamics and bioenergetics: ATP as energy molecules, Role of mitochondria in ATP synthesis, other important high energy compounds and their significance; Laws of thermodynamics, Oxidation-reduction reactions.

MODULE II- Carbohydrate metabolism: Carbohydrate metabolism and energetics: glycolysis, gluconeogenesis and TCA cycle and their significance

MODULE III- Lipid metabolism: Lipid metabolism overview and their significance. Biosynthesis of lipid and beta-oxidation and their relevance

MODULE IV- Amino acid metabolism: Amino acid biosynthesis and catabolism and their significance, Urea cycle and its significance.

MODULE V- Nucleic acid metabolism: Biosynthesis (*de novo* and salvage pathways) and catabolism of nucleic acids and their significance

REFERENCES

1. Nelson, D. L., Cox, M. (2017). Lehninger Principles of Biochemistry: International Edition. United Kingdom: Macmillan Learning.
2. Rodwell, V. W., Weil, P. A., Kennelly, P. J., Bender, D., Botham, K. M. (2018). Harp er's Illustrated Biochemistry Thirty-First Edition. United States: McGraw Hill LLC.
3. Voet, D., Voet, J. G. (2021). Biochemistry. Singapore: John Wiley & Sons, Limited.
4. Holtzhauer, M. (2006). Basic methods for the biochemical lab. Germany: Springer.
5. Satyanarayana, U. (2017). Biochemistry - E-book. India: Elsevier Health Sciences.

24-811-0403- ESSENTIAL CELL BIOLOGY (4C; 4L+0T+0P) (Academic Level 200)

Course description: The objective of the course is to help the students to learn and develop an understanding of a cell as a basic unit of life. This course is designed to enable them to understand the functions of cellular organelles and how a cell carries out and regulates cellular functions. The course will also provide an overview of classical and modern cell biology-based techniques.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Explain the fundamental principles of cell biology.	Understand
C.O. 2: Identify and differentiate the cellular organelles using microscopy.	Analyse
C.O. 3: Identify and differentiate plant, animal and microbial cells based on morphological features and size.	Analyse
C.O. 4: Describe the process of cell signalling and its role in cellular functions	Understand
C.O. 5: Discuss various techniques in cell biology and list the advances made in the field of cell biology and their applications.	Remember

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2	2	2					
CO3	2	2	2	2				
CO4	2	1						
CO5	2	1	1					

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- History, development and scope of cell biology; discovery of cells; cell theory and its modern version. Cell and its components: basic types of cells- prokaryotic and eukaryotic, nature and comparison. Ultra-structural organization and functions: Plasma membrane- ultrastructure- fluid mosaic model, functions of the plasma membrane.

MODULE II - Cellular Organelles and their functions: Mitochondria, Endoplasmic reticulum, Golgi bodies, Lysosomes, Microbodies, Ribosomes, Proteasomes, Centrioles, Cytoskeleton, Nucleus-nuclear envelope and Nucleolus, chromosomes, Nucleoproteins, Nucleosome model of DNA organization, structural and numerical variations of chromosomes, Polytene, Lamp brush and B chromosomes.

MODULE III - Histology-Animal histology: Tissues: Epithelial tissue; types, characteristics and functions, Blood, Bone, Cartilage and Adipose tissues, Muscle tissue; Cellular and molecular mechanism of muscle contraction, Nervous tissue. Plant histology- Plant tissues; meristematic & permanent (simple complex tissues), tissue systems.

MODULE IV-Overview of cell signalling, communication between cells, plasma membrane and nuclear receptors; hormones; ion channels; secondary messengers; Cell Division: cell cycle- G1, S, G2, and M phases, amitosis. Mitosis & Meiosis; Cell cycle and Regulation, cancer cells, and cell death.

MODULE V- Cell Biology Techniques: **Cell Isolation** (plants and Animals), Microscopy and Micrometry: Fixed and live-cell imaging, Radioisotopes, Fluorescent Probes/Dyes as tools to study cellular functions, basics of FACS.

REFERENCES:

1. Campbell Biology, 10th Edition. Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson
2. Biology: A Global Approach (Paperback) by Jane B. Reece, Steven A. Wasserman 3) Molecular Biology of Gene: Watson et al.,
3. Molecular Cell Biology: By Darnell, Lodish, Baltimore
4. Concepts of Genetics William S Klug and M. R. Cummings, Gerald Karp, Cell Biology
5. Wayne M. Becker et al., World of the Cell
6. Bruce Alberts et al., Essential Cell Biology 4th Edition
7. Richard Goldsby and Thomas J Kindt, Kuby Immunology
8. Cooper, Geoffrey M., and Robert E. Hausman. 2009. *The cell: a molecular approach*. Washington, D.C.: ASM Press.
9. De Robertis & De Robertis: Cell & Molecular Biology, Lea & Febiger, 1987

24-811-0404- CELL BIOLOGY AND BIOCHEMISTRY LAB (4C; 0L+0T+8P) (Academic Level 200)

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Manipulating DNA molecule with restriction enzymes	Apply
C.O. 2: Demonstrate the steps involved in molecular cloning and transformation	Analyse
C.O. 3: Apply various staining techniques to visualize animal and plant cells	Analyse
C.O. 4: Determine the enzyme activity	Apply
C.O.5: Perform the qualitative and quantitative analysis of biomolecules	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1			2	2				
CO2			2					
CO3			2	1	1			
CO4			2	1				
CO5			2	1	1	1		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

LIST OF PRACTICAL

1. Quantitative analysis of biomolecules
2. Determination of enzyme activity using spectrophotometric assays.
3. Analysis of amino acid metabolism using chromatographic techniques (e.g., HPLC or TLC).
4. Staining and observation of various organelles under the microscope
5. Stages of Mitosis (Onion tip)
6. Blood smear preparation and its analysis.
7. Imaging of various murine cell types: Epithelial cells, endothelial cells, neuronal cells, immune cells.
8. Identifying permanent tissues from plant sections (parenchyma, collenchyma, sclerenchyma, xylem vessels)
9. Identifying apoptotic and necrotic cells by the cell staining procedure

24-811-0405 SCIENTIFIC WRITING AND COMMUNICATION IN BIOLOGY (3C; 3L+0T+0P) (Academic Level 200)

Course Description

This course is designed to equip students with the skills necessary to effectively communicate scientific concepts, research findings, and ideas within the field of biology. Through a combination of lectures, workshops, and practical exercises, students will learn how to write scientific papers, reports, and proposals, as well as how to deliver clear and engaging presentations. Emphasis will be placed on critical thinking, clarity, accuracy, and ethical considerations in scientific communication.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Understand the principles of scientific writing and communication.	Understand
C.O.2: Develop proficiency in writing various scientific documents, including research papers, lab reports, and grant proposals.	Analyse
C.O. 3: Learn how to organize and present scientific information in a clear, concise, and logical manner.	Analyse
C.O. 4: Enhance critical thinking skills through the evaluation and analysis of scientific literature.	Apply
C.O.5: Practice effective communication strategies for oral presentations and scientific discussions.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2						2	
CO3					2	2	2	2
CO4						2	1	
CO5						2	1	2

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module I: Introduction to Scientific Writing and Communication- Overview of scientific communication; Importance of effective communication in biology; Understanding the target audience; Ethical considerations in scientific writing

Module II: **Writing Scientific Papers**- Structure and organization of scientific papers; Writing abstracts, introductions, methods, results, and discussions; Citation and referencing styles (e.g., APA, MLA); Peer review process and responding to reviewer comments

Module III: Lab Reports and Technical Writing- Guidelines for writing lab reports and technical documents**;** Writing clear and concise methods sections**;** Data presentation and interpretation**;** Incorporating figures, tables, and graphs

Module IV: Research Proposals and Grant Writing-Components of research proposals**;** Grant writing strategies and techniques**;** Understanding funding agencies and grant applications**;** Budgeting and resource allocation

Module V: Oral Presentations and Scientific Talks- Planning and organizing oral presentations**;** Effective delivery techniques and public speaking skills**;** Visual aids and slide design**;** Handling questions and engaging with the audience **Communication in the Digital Age-** Writing for online platforms and social media**;** Blogging, science communication, and outreach**;** Using multimedia tools for scientific communication**;** Digital ethics and online presence

Suggested readings

1. R. Barrass 1978. Scientists Must Write. John Wiley and Sons, New York.
2. C. S. Loban and M. Schefter 1992. Successful Lab Reports: A Manual for Science Students. Cambridge University Press.
3. V. E. McMillan 1988. Writing Papers in the Biological Sciences. St Martin's Press, NewYork.
4. J. A. Pechenik 1997. A Short Guide to Writing About Biology. Addison-Wesley Pub Co.
5. "Writing for Science: A Practical Handbook for Science, Engineering, and Technology Students" by Heather Silyn-Roberts
6. Scientific journals and articles
7. Online writing guides and resources
8. Writing workshops and tutorials

SEMESTER V

SEMESTER V

24-811-0501- PLANT DIVERSITY I
(Algae/Fungi/Bryophytes/Pteridophytes/Palaeobotany) (4C; 4L+0T+0P)
(Academic Level 300)

Course description: The course will cover the diversity, life forms, life cycles, morphology and importance of algae and various fungal groups and their association (lichens). The concepts of phytopathology, plant diseases, causal organisms and their control will also be covered. This course aims at making familiarity with special groups of plants-Bryophytes and pteridophytes, joined together by a common feature of sexual reproduction involving antheridia and archegonia. As these groups are primitive, the palaeobotany fossil forms are also included to have an evolutionary outlook. Study of morphology, anatomy, reproduction and developmental changes therein through typological study should create a knowledge base for understanding plant diversity, economic values, and the taxonomy of lower groups of plants.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Explain why fungi are treated as a separate kingdom and not included in the plant and animal kingdom	Understand
C.O. 2: Classify algae, fungi, bryophytes, pteridophytes	Understand
C.O. 3: Differentiate fungi, lichens, bryophytes and pteridophytes based on morphology	Analyse
C.O. 4: Identify various plants and their organization in nature through field trips and the collection and conservation of plant samples	Remember
C.O. 5: Discuss the significance of palaeobotany in terms of understanding the evolution and emergence of plant diversity	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	3							
CO3	2							
CO4	3							
CO5	2	1						

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I-Algae: Classification (F.E Fritsch), Principles and modern trends in the taxonomy of algae. Morphology, anatomy, life cycle and reproductive biology of a) Cyanophyceae- Nostoc b) Chlorophyceae-Chlorella, Volvox, Oedogonium and Chara c) Xanthophyceae-Vaucheria d) Bacillariophyceae-Pinnularia e) Phaeophyceae-Sargassum f) Rhodophyceae- Polysiphonia. Contributions of Indian Algologists. Economic importance of algae. Applied aspects: Biofuel production, food supplements, pharmaceutical industries, algal blooms, commercial cultivation of algae.

MODULE II- Fungi: Eukaryotic, heterotrophic organisms, chitinous cell walls, multicellular (hyphae/mycelium) or unicellular (yeasts), Reproduction sexually and asexually via spores. Classification: Major classes: Zygomycetes, Ascomycetes, Basidiomycetes, Deuteromycetes, Based on reproductive structures and life cycles. Morphology and Ultrastructure: Hyphae: Thread-like structures forming mycelium, Spores: Reproductive cells produced for dispersal. Growth and Reproduction: Asexual: Budding, fragmentation, or asexual spores, Sexual: Fusion of specialized cells to form spores, Characteristics of Mushrooms and Cultivation: Fruiting bodies of Basidiomycetes with caps, stalks, and gills, cultivated commercially using substrates and controlled environments.

MODULE III- Bryophytes: classification- general account, Study of habit, thallus organization, vegetative and sexual reproduction, and alternation of generation of the following types (Developmental details are not required)*,* Type study: *Riccia, Marchantia, Anthoceros and Funaria*. Economic importance of Bryophytes

MODULE IV- Pteridophytes: Classification, General characters, morphological and anatomical features, life cycle and reproductive biology, Type study: *Psilotum*, *Selaginella*, *Pteris* and *Marsilea*, Stelar evolution in Pteridophytes, Economic importance of Pteridophytes.

MODULE V- Palaeobotany: Geological time scale, Fossil and fossil formation, types of fossils, fossil age calculation methods, the importance of fossils, Fossil Pteridophytes- *Rhynia,* Lepidodendron, Lepidocarpon. Fossil gymnosperms-*Lygnopteris.*

REFERENCES

1. Chopra RN and P. K. – Biology of Bryophytes - Wiley Eastern Ltd. New Delhi
2. Parihar N.S. – An introduction to Bryophyta - Central Book Depot. Allahabad
3. Vasishta B. R. - Bryophyta - S. Chand and Co. New Delhi
4. Coulter. J. M. - and Chamberlain C. J. (1958) – Morphology of Gymnosperms - Central Book Depot, Allahabad
5. Gupta V.K. and Varshneya U. D (1967) – An Introduction to Gymnosperms – Kedarnath, Ramnath – Meerut.
6. Smith G.M. (1955) - Cryptogamic Botany – Vol.II – Mc Graw Hill Co. New Delhi
7. Sporne K. R. (1967) - Morphology of Gymnosperms - Hutchin University Library, London
8. Vashista B. R. (1993) - Pteridophyta – S. Chand and co. New Delhi
9. Vashista B. R. (1993) Gymnosperms - S. Chand and co. New Delhi
10. Andrews H.N. (1967) - Studies on Palaeobotany – C. J. Felix.
11. Arnold C. A (1947) - Introduction to Palaeobotany - McGraw Hill Co. New Delhi.

24-811-0502- PLANT DIVERSITY II (Gymnosperms and Angiosperms)
(4C; 4L+0T+0P) (Academic Level 300)

Course Description: The course aims to provide knowledge of gymnosperms and angiosperms. The economic importance of diverse plants that offer resources to human life will be covered. The course also aims to provide knowledge of the plants used by the local communities, tribal, and ethnic groups, and their nutritive and medicinal value.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcomes	Cognitive Level
C.O. 1: Explain the general characteristics of gymnosperm and angiosperm.	Understand

C.O. 2: Differentiate between gymnosperms and angiosperms based on morphological character	Analyse
C.O. 3: Compare the diversity among plants based on morphology, anatomy, life cycle.	Analyse
C.O. 4: Identify the local flora having economic and ethnobotanical importance for exploring the natural products with potential medicinal implications	Remember
C.O. 5: Classify various plants based on pollen architecture	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	3		2					
CO3	2		1					
CO4	3	2	2					
CO5	2		2					

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I-Gymnosperms: Classification, general features, morphology, anatomy, life cycle and reproductive biology of Cycadopsida-*Cycas,* Coniferopsida-*Pinus* and Gnetopsida-*Gnetum*. Evolutionary trends in gymnosperms and their economic importance.

MODULE II-Angiosperms: Principles and importance of taxonomy, Herbarium technique, BSI and ICBN. Systems of classification. Outline classification of Bentham & Hooker and Cronquist. APG systems of classification. The concept of taxon and Taxonomic hierarchy, plant nomenclature. A brief reference to the citation of the author. Chemotaxonomy.

MODULE III-Morphology: Morphology of root, stem, leaves and inflorescence. Floral morphology and structure, the symmetry of flower, aestivation, placentation; floral diagram and floral formula, Fruit types: simple, aggregate, and multiple. Seeds: albuminous and exalbuminous. Palynology: Pollen architecture, Pollen transfer, Pollen–pistil interaction. Pollination and its types. Pollen allergy, palynological calendars and pollen analysis of honey.

MODULE IV-Economic botany: Binomial, family and morphology of useful parts of Maize, soya bean, sugarcane, cocoa, tea, pepper, cardamom, potato, banana, mango, cashew nut, tomato, vinca, opium, teakwood.

MODULE V-Ethnobotany: Ethnobotany and Folk medicines. Ethnobotany in India, Methods to study ethnobotany -Fieldwork, Herbarium, Ancient Literature, Archaeological findings, temples and sacred places. Applications of Ethnobotany: Medicinal plants of tribals with reference to Thuthi, Kadukkai, Perandai, Avarai, Kandankathari, Oomathai, Veliparuthi, Asparagus and Boerhaavia. Legal aspects-biopiracy, IPR & traditional knowledge,

REFERENCES

1. Sivarajan, V.V. Introduction to the principle of plant taxonomy, Oxford and IBH Publishing Company
2. Pandey SN and Misra SP, 2008 Taxonomy of Angiospenus; Ane Books Pvt. Ltd.
3. Verma V, 2009 Textbook of Economic Botany; Ane Books Pvt. Ltd.

4. Kapoor LD, 2001 Handbook of Ayurvedic Medicinal Plants, CRC Press New York, Ane Books Pvt. Ltd
5. Jones, S.B. Jr. and Luchsinger, A.E. 1986. Plant Systematics (2nd edition). McGraw-Hill Book Co., New York.
6. Lawrence. G.H.M. 1951. Taxonomy of Vascular Plants. Macmillan, New York.
7. Naik, V.N. 1984. Taxonomy of Angiosperms. Tata McGraw Hill, New York.
8. Singh. G. 1999. Plant Systematics: Theory and practice Oxford & IBH Pvt, Ltd.New Delhi.
9. Nordenstam. B.., El-Gazaly, G. and Kassas. M. 2000. Plant Systematics for 21st Century
10. S.K. Jain. Glimpses of Ethnobotany. Oxford and IBH Publishing Company, New Delhi.

24-811-0503- NON-CHORDATES (4C; 4L+0T+0P) (Academic Level 300)

Course description: The course will help the students to understand the features of the Kingdom Animalia and the systematic organization of the animals based on their evolutionary relationships, structural and functional affinities. The course will also make the students aware of the characteristic morphological and anatomical features of diverse animals; the economic, ecological and medical significance of various animals in human life; and will create interest among them to explore the animal diversity in nature.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcomes	**Cognitive Level**
C.O. 1: Discuss the importance of systematics and taxonomy of animals.	Understand
C.O. 2: Compare the adaptive features of non-chordates living in varied habits and habitats.	Analyse
C.O. 3: Classify non-chordates as per their distinguishing features.	Understand
C.O. 4: Examine the anatomy of different classes of non-chordates that enables survival advantages in their habitat	Analyse
C.O. 5: Identify various non-chordates based on systematics	Remember

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	3							
CO2	2	1						
CO3	2	2	1					
CO4	2		2	1				
CO5	3	2	2					

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- Basis of classification of multicellular animals: Cleavage; Germ layers; Symmetry; Body cavity; Concept of Protostomia *vs.* Deuterostomia.

MODULE II- General characteristics and classification (up to Class/subclass level) of Major Phyla: Protozoa; Porifera; Cnidaria; Ctenophora; Platyhelminthes, Annelida, Arthropoda; Mollusca, Echinodermata.

MODULE III-A general account of structure and reproduction of *Paramecium*; *Sycon*; *Obelia*; *Aurelia*; Planaria (*Dugesia*); *Fasciola*; *Hirudinaria*; *Pila*; Prawn; Starfish: *Peripatus*; *Limulus*; *Balanoglossus*.

MODULE IV- Concept of Minor Phylum and their importance in the study of non-chordate evolution; General characteristics of Aschelminthes (Rotifera, Acanthocephala, Nematoda, Nematomorpha, Priapulida, Kinorhyncha, Gastrotricha), Ectoprocta; Chaetognatha; Echiura, Sipunculida, Pogonophora; Lophophorata (Phoronida, Brachiopoda, Bryozoa); Hemichordata

MODULE V- Reproduction in Protozoans; Theories on the origin of Metazoan; Canal system in sponges; Metagenesis in cnidarians; Coral and coral reefs; Nephridial system in annelids; Trochophore larva and its evolutionary significance; Shell in molluscs; Water vascular system in echinoderms; Larval forms of Echinoderms and their significance.

REFERENCES

1. Barnes: The invertebrates (3rd ed. 2001, Blackwell)
2. Moore: An introduction to the invertebrates (2001Cambridge)
3. Ekambaranath Ayar: A manual of Zoology, Part I – Invertebrata, (1973, S. Vishwanathan)
4. Kotpal, Agarwal and Khetrapal: Modern Textbook of Zoology: Invertebrate, (1976, Rastogi)
5. Marshall: Parker and Haswell Textbook of Zoology, Vol. I (7th ed. 1972, Macmillan)
6. Nigam: Biology of Non-chordates (1985, S. Chand)
7. Jordon and Verma: Invertebrate Zoology (1995, S. Chand)
8. Millar and Harley: Zoology (6th ed. 2005, Brown)

24-811-0504- CHORDATES (4C; 4L+0T+0P) (Academic Level 300)

Course description: The course is designed to provide the scope and historical background of chordates. It will impart knowledge regarding basic concepts of the origin of chordates and make the students understand the characteristics and classification of animals with notochords. An adequate explanation to the students regarding various mechanisms involved in the thriving survival of the animals within their geographic realms will create interest among students.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Describe different classes of chordates, level of organization and evolutionary relationship between different subphyla and classes.	Understand
C.O. 2: Differentiate the members of each class based on morphology, anatomy, life cycle and other distinguishing features.	Analyse
C.O. 3: Identify the similarities and differences in life functions among various groups of animals in Phylum Chordata.	Remember
C.O. 4: Compare the members based on anatomical features concerning function (circulatory, nervous and skeletal system of chordates).	Analyse
C.O. 5: Discuss the pattern of vertebrate evolution, organization and functions of various systems.	Remember

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2	2						
CO3		3	2					
CO4		2	2	1				
CO5	2	2						

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- General characteristics, classification of the following up to sub-classes/ orders with examples and affinities of the following: Protochordata (Urochordata, Cephalochordata); Cyclostomata; Pisces; Amphibia; Reptilia; Aves; Mammalia; Origin of vertebrates, lungfishes; Amphibians, birds and mammals.

MODULE II- Functional morphology of *Branchiostoma*, *Petromyzon*; Mullet, Frog; *Calotes*, fowl and rabbit.

MODULE III-Adaptive radiation in vertebrates: Aquatic; Terrestrial; Aerial; Arboreal; Fossorial.

MODULE IV- Evolution of aortic arches; jaw suspension; respiratory organs (gills, skin, lungs, air sacs, accessory respiratory organs), kidney, skull in reptiles; brain (cerebral hemisphere, cerebellum).

MODULE V- General considerations of integumental derivatives Scales, feathers, hair, claws, nails, hoofs, horns, antlers, glands), stomach in ruminants, Parental care in amphibians; snake venom; bird migration; flightless birds; dentition in mammals.

REFERENCES

1. Aiyar. A Manual of Zoology, Vol.2.
2. Kotpal: Modern Textbook of Zoology Vertebrates (2003, Rastogi)
3. Nigam: Biology of Chordates (1983, S Chand)
4. Harvey *et.al*: The Vertebrate Life (2006)
5. Colbert *et.al*: Colbert’s Evolution of the Vertebrates: A History of the Backboned Animals through time (5th ed, 2002, Willey-Liss)
6. Hildebrand: Analysis of Vertebrate Structure (4th ed, 1995, John Willey)
7. Jordan &Verma: Chordate Zoology (1998, S.Chand)
8. McFarland *et.al*: Vertebrate Life (1979, Macmillan Publishing)
9. Parker & Haswell: Textbook of Zoology, Vol. II (1978, ELBS)
10. Romer & Parsons: The Vertebrate Body (6th ed 1986, CBS Publishing Japan)
11. Sinha, Adhikari & Ganguli: Biology of Animals Vol.II (1988, New Central Book Agency)

24-811-0505- ANIMAL AND PLANT LAB (4C; 0L+0T+8P) (Academic Level 300)

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	**Cognitive Level**
C.O. 1: Identify and Evaluate the vegetative and reproductive structures of fungi, Algae, Bryophytes, and Pteridophytes	Analyse

C.O. 2: Apply taxonomic protocols and Classify algae, fungi, bryophytes, pteridophytes	Apply
C.O. 3: Differentiate fungi, lichens, bryophytes and pteridophytes based on morphology	Analyse
C.O. 4: Identify various plants and their organization in nature through field trips	Remember
C.O. 5: Collection and conservation of plant samples	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2					
CO2	2	2	2					
CO3	2	2	2	1				
CO4	2	2	2	1	2			
CO5	3		2				2	2

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

LIST OF PRACTICAL

Plant Diversity

1. Study of vegetative and reproductive structures of Nostoc, *Chlamydomonas* (electron micrographs), *Oedogonium*, *Vaucheria*, and *Polysiphonia* through permanent slides.
2. Fungal staining by Lactophenol cotton blue
3. *Phytophthora*: Specimens/photographs
4. *Agaricus*: Specimens of button stage and full-grown mushroom; LS of gills.
5. Lichens: Study of growth forms of lichens (crustose, foliose and fruticose)
6. *Riccia*- Habit- V.S of the thallus, VS through archegonia, antheridia and sporophyte
7. *Marchantia*- Habit, thallus VS, male receptacle and female receptacle- entire and VS, thallus gemma-entire and VS, Sporophyte VS
8. *Cycas*- T.S of leaf, T.S. of the coralloid root, Male and female cone, ovule (LS)
9. *Pinus*- T.S. of the stem, T.S. of the needle, male and female cone VS
10. Students must submit practical records, Herbarium sheets (15 No's) and Field books at the time of the practical examination.
11. Identify the economic products obtained from the plants mentioned under Economic Botany
12. Critical notes on plants of ethnobotanical relevance as mentioned in the syllabus.

Non-Chordates

1. Nereis - parapodium
2. Earthworm – body setae, nervous system
3. Scales of butterfly wing
3. Cockroach – mouth parts /salivary gland/nervous system
4. Honeybee – mouthparts/mosquito - mouthparts
5. Prawn – appendages (Any Three- Maxillipeds1,2,3, Chelate leg, First abdominal appendage) nervous system
6. Spot Identification: Taxonomy Identification, Classification up to class and a brief note of the following specimens.

I. Protista – Actinophrys, Noctiluca, Paramecium, Opalina – any 2
II. Phylum Porifera – Euplectella, Spongilla- any 1

III. Phylum Cnidaria – Hydra, Obelia, Physalia, Aurelia, Sea anemone, Madrepora – any 3
IV. Phylum Nematoda – Ascaris- male and female (entire)
V. Phylum Platyhelminthes – *Bipalium*, *Fasciola*, *Taenia solium* – any 1
VI. Phylum Annelida – Earthworm, Nereis, Leech, Aphrodite, Arenicola – any 1
VII. Phylum Onychophora – Peripatus
VIII. Phylum Arthropoda – Cockroach, Limulus, Eupagurus, Sacculina, Honeybee, Lepisma, Scorpion – any 3
IX. Phylum Mollusca – Chiton, Pila, Xancus, Dentalium, Perna, Mytilus, Teredo, Sepia, Octopus. – any 2
X. Phylum Echinodermata – Starfish, Brittle star, Sea urchin, Sea cucumber, Sea lily – any 2

Chordates

1. *Branchiostoma*- External features; Mounting of the oral hood, velum and pharyngeal wall
Study of the following slides: T.S. through the oral hood, midgut diverticulum, pharyngeal region, gonads and post-oral region of the intestine; study of *Pyrosoma, Salpa, Doliolum*
2. Mounting of the cycloid and ctenoid scales; mounting of chromatophores of fish; study of different types of feathers: Contour, filoplume and down feathers
3. Vascular system- Heart and afferent and efferent branchial vessels of Mystus/ *Cirrhinus sp.;* Arterial and venous systems of rat
4. Respiratory system: Accessory respiratory organs of *Heteropneustes, Channa, Clarias*
5. Nervous system of a fish
6. Histology of tooth, tongue, oesophagus, stomach, intestine, pancreas, liver, spleen, kidney cartilage, bone of mammals
7. Study of the following museum specimens/animals from the Zoo or field
    1. Cyclostomata: *Petromyzon*
    2. Chondrichthyes: *Scoliodon*
    3. Osteichthyes
    4. Amphibia
    5. Reptilia
    6. Aves
    7. Mammalia

24-811-0506 INTRODUCTION TO CELL CULTURE TECHNIQUES
(3C; 3L+0T+0P) (Academic Level 200)

Course Description: The Plant and Animal Cell Culture Techniques course provides students with a comprehensive understanding of the principles, methodologies, and applications of cell culture techniques in both plant and animal systems. Through lectures, laboratory demonstrations, and hands-on training, students will learn the fundamentals of establishing and maintaining plant and animal cell cultures, as well as techniques for genetic transformation, propagation, and characterization. Emphasis will be placed on mastering sterile technique, media preparation, and experimental design relevant to both plant and animal cell culture research.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcomes	Cognitive Level
C.O. 1: Understand the principles and importance of cell culture in plant and animal research.	Understand

C.O. 2: Gain proficiency in sterile technique and aseptic practices specific to plant and animal cell culture.	Apply
C.O. 3: Learn methods for establishing, maintaining, and characterizing plant and animal cell cultures.	Analyse
C.O. 4: Develop skills in genetic transformation techniques applicable to both plant and animal cells.	Analyse
C.O. 5: Explore advanced applications and recent advancements in plant and animal cell culture research.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2		1					
CO3		2	2	2				
CO4			2		1			
CO5				2	1	1		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I. Introduction to Plant and Animal Cell Culture- Definition and historical context; Importance of cell culture in plant and animal research; Types of cells used in culture: Protoplasts, cell lines, primary cultures

MODULE II. **Laboratory Safety and Aseptic Technique**- Biosafety levels and laboratory regulations specific to plant and animal cultures; Sterile technique: Proper handling of plant tissues, animal cells, and culture media; Prevention and management of contamination in plant and animal cultures

MODULE III. Culture Media and Growth Conditions- Plant cell culture media: MS, B5, Woody Plant Medium; Animal cell culture media: DMEM, RPMI, MEM; Growth regulators and supplements for plant and animal cultures

MODULE IV. Plant Cell Culture Techniques-Isolation and culture of plant tissues and organs; Callus induction, organogenesis, and somatic embryogenesis; Regeneration of whole plants from cultured cells or tissues. **Animal Cell Culture Techniques-**Isolation and culture of animal cell lines and primary cultures; Sub-culturing and passaging animal cells; Cryopreservation and storage of animal cell cultures

MODULE V. Applications of Plant and Animal Cell Culture-Production of secondary metabolites in plant cultures; Recombinant protein expression in animal cell cultures; Disease modelling, drug screening, and biopharmaceutical production. **Ethical Considerations and Regulatory Compliance**-Ethical guidelines for plant and animal cell culture research; Compliance with regulations: Institutional policies, animal welfare; Case studies and discussion of ethical dilemmas

References

1. "Plant Tissue Culture: Techniques and Experiments" by Roberta H. Smith
2. "Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications" by R. Ian Freshney
3. "Plant Cell Culture Protocols" edited by Robert J. Nicklin and John M. Carter
4. "Animal Cell Culture: Essential Methods" edited by John M. Davis and Jeanne L. Becker

SEMESTER VI

SEMESTER VI

24-811-0601- EVOLUTION AND DEVELOPMENTAL BIOLOGY (4C; 4L+0T+0P) (Academic Level 300)

Course description: This course offers a chance for students to learn about deciphering evidence ranging from fossil records to molecular data and arranges them to establish phylogenetic relationships of species and provides a platform to understand various forces which bring about variations among populations of a species and cause them to diversify into new species. The course also focuses on Developmental Biology to provide four-dimensional thinking for students to truly understand the patterns and process of embryonic development, body plan, fate map, induction, competence, regulative and mosaic development, molecular and genetic approach for the study of developing embryo which is not necessarily shared with any other disciplines in the biological sciences.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Describe the relationship of the evolution of various species and the environment they live in	Understand
C.O. 2: Explain the molecular events associated with the developmental process of living forms from a single fertilized egg, the zygote.	Understand
C.O. 3: Discuss the stages of developmental processes that lead to the establishment of the body structure of multicellular organisms	Understand
C.O. 4: State the importance of stem cell therapy, in vitro fertilization and amniocentesis etc.	Remember
C.O. 5: Describe the evolution of man, speech, language and culture,	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	3	2						
CO3	2							
CO4	2							
CO5	2						1	1

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I

Biochemical and genomic evolution: The evolutionary history of proteins, Evolution of gene, gene families, molecular drive, Amino acid sequence divergence in proteins, Nucleotide sequence divergence in DNA noncoding RNA, micro RNAs, the phylogenetic utility of RNA structures, Hitchhiker's Guide to evolving networks, protein-protein interaction network, the evolution of metabolic networks, and concept of molecular clock, Outline of origin of prokaryotic and eukaryotic genomes

MODULE II

Origin of Higher Categories, Origin of Metazoa, theories of origin, Origin and evolution of Trilobites, vertebrate groups- Pisces, Amphibia, Reptilia, Aves and Mammals. The evolutionary history of neural integration, endocrine systems, Hormones Phylogenetic gradualism, and punctuated equilibrium, Micro and Macroevolution. Stages in Primate

Evolution- Prosimii, Anthropoidea and Hominids. Factors in human origin-Hominid fossils, Cytogenetic and Molecular basis of the origin of the man-African origin of modern man-Mitochondrial Eve, Y chromosomal Adam, - early migration, hunter-gatherer societies.

MODULE III

Developmental Biology: Introduction theories- Preformation, Epigenesis, Recapitulation and Germplasm. Subdivisions of Developmental biology. Spermatogenesis and oogenesis, the structure of Graafian follicle, typical egg and sperm, Polarity of egg, egg envelops; classification of eggs based on different criteria. Fertilization: Agglutination, sperm penetration, activation of egg, amphimixis; physiological and biochemical changes during and after fertilization. Parthenogenesis, Cleavage, Morula formation, blastulation and blastocyst.

MODULE IV

Cell differentiation: totipotency, pluripotency and unipotency of embryonic cells. Determination and differentiation in embryonic development. Gene action, Drosophila as a model organism (a brief account only), Homeotic genes and Hox genes, Presumptive organ forming areas and fate maps, Gastrulation, morphogenetic movements, epiboly and emboly, the concept of germ layers, derivatives of germ layers.

MODULE V

Human - implantation, pregnancy, parturition. Placentation in mammals - different types of the placenta, functions, Teratology. Experimental embryology, developmental disorders. In vitro fertilization and embryo transfer experiments in mammals and test-tube babies, prenatal diagnosis, and sex determination methods – amniocentesis chorionic villus sampling, ultrasound scanning. Embryonic and adult stem cell research and stem cell therapy.

REFERENCES

1. Dobzhansky Th. et al. (1976): Evolution. Surjeet Publ.
2. Freeman S. and Jon C. Herron (1998): Evolutionary Analysis. Prentice-Hall
3. Futuyma D. J. (1998): Evolutionary Biology. Sinauer
4. Hartl D. L. and A. G. Clark (1989 & 1997): Principles of Population Genetics. Sinauer
5. Li Wen-Hsiung and Dan Graur (1991): Fundamentals of Molecular Evolution. Sinauer
6. Strickberger M. W. (2000): Evolution. Jones and Bartlett
7. White M. J. D. (1978): Modes of Speciation. Freeman
8. P.C. Jain. (2007). Elements of Developmental Biology, 6th Edn. Rastogi Publications
9. Begley, D.J., Firth, J.A. and Houtt, J.R.S. (1980). Human Reproduction and Developmental Biology, MacMillan Press Ltd.
10. Gilbert. S.F. (2000). Developmental Biology. Sinauer Associates, Inc. Publishers.
11. Huettner, A.F. (1959). Comparative Vertebrate Embryology. MacMillan.
12. Nelson. (1960). Comparative Embryology of Vertebrates. MacMillan.

24-811-0602- PARASITOLOGY AND IMMUNOLOGY (4C; 4L+0T+0P) (Academic Level 300)

Course description: Parasitology will enable us to diagnose parasites correctly, understand their life cycle and control them effectively and use some of them as biocontrol agents. Parasitology; especially the study of the life cycles of parasites; has helped in defying the stigmas and religious taboos for many societies freeing many of the people from superstition and ill health. The course shall surely skill the students to see, appreciate and understand the diversity of parasites in the whole spectrum of the study of life. Also, provide an overview on the immune system and its function. The course shall also make the students aware of the possible scopes of the subject which include research and applied aspects including entrepreneurial works.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Explain the fundamentals of parasitology, parasitic invasion in both plants and animals; applicable to medical and agriculture aspects.	Understand
C.O. 2: Describe the measures to prevent a parasitic attack, Diagnosis, Prophylaxis and Treatment of parasitic infections.	Understand
C.O. 3: Discuss the basics of immunology and list immunological components	Understand
C.O. 4: Differentiate various blood cells by microscopy	Analyse
C.O. 5: Differentiate various parasites as per morphology	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	3						2	
CO3	2							
CO4	2	1	1					
CO5	2		1			1		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I

Introduction to Parasitology Brief introduction of Parasitism, Parasite, Parasitoid and Vectors, Host-parasite relationship, Ecology of parasites, Population dynamics of parasite and establishment of the parasite population in the host body, the evolution of parasitism, evolution and coevolution of parasite with respect to host strategy, Important case studies in the field of Parasitology including some historical events such as the role of the mosquito control and the successful completion of the construction of the Panama canal.

MODULE II

Parasitic Protists Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Entamoeba histolytica*, *Giardia intestinalis*, *Trypanosoma gambiense*, *Leishmania donovani*, *Plasmodium vivax*. Parasitic Platyhelminthes Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Fasciolopsis buski, Schistosoma haematobium, Taenia solium* and *Hymenolepis nana*.

MODULE III

Parasitic Nematodes Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Ascaris lumbricoides*, *Ancylostoma duodenale*, *Wuchereria bancrofti* and *Trichinella spiralis*. Study of the structure, lifecycle and importance of *Meloidogyne* (Root-knot nematode), Pratylencus (Lesionnematode), Parasitic Arthropoda Biology, importance and control of ticks, mites, *Pediculus humanus, Xenopsylla* *cheopis* and *Cimex lectularius*. Crustacean parasites. Parasitic Vertebrates A brief account of parasitic vertebrates; Cookiecutter Shark, Candiru, Hood Mockingbird and Vampire bat.

MODULE IV

Introduction, history, development and scope, Immunity: definition, classification of immunity. Innate and adaptive, Components of the Immune system: organs and tissues of the immune system. Antigens and Antibody, epitopes, antibodies (Immunoglobulins) - definition, the general structure of Ig, Ig determinants, precipitation reactions, agglutination reactions, complement fixation, neutralization, opsonization, complement system, major histocompatibility complex (MHC), types of immune responses- humoral immune response, cellular immune response, mention cytokines, define immunological memory, immunological tolerance, and immune suppression.

MODULE V

Hypersensitivity/allergy and Autoimmunity: definitions, classification- types I, II, and III, immunodeficiency diseases, Acquired Immune Deficiency Syndrome (AIDS); Auto immunity-definition, mechanism, mention AI diseases; transplantation immunity, graft versus host reactions, Immunization, and vaccination.

REFERENCES

1. Foundations of Parasitology, Roberts L.S. and Janovy J., McGraw-Hill Publishers, New York, USA.
2. Modern Parasitology: A Textbook of Parasitology, FEG Cox., Wiley-Blackwell, U. K.
3. Parasitology: A Conceptual Approach, Eric S. Loker, Bruce V. Hofkin
4. Kuby Immunology, Richard, Thomas, Barbara, Janis, W. H. Freeman and Company [Latest edition].
5. Immuno Biology- The immune system in health and disease, Janeway, Travers, Walport and Shlomchik, Garland Science Publishing [Latest edition].
6. Essentials of Immunology, David, Brostoff and Roitt, Mosby & Elsevier Publishing
7. Fundamentals of Immunology by William E. Paul, Lippincott Williams & Wilkins Publishing
8. Cellular and Molecular Immunology by Abul K. Abbas, Andrew H. Lichtman, Shiv Pillai, Elsevier Publishing

24-811-0603- PARASITOLOGY AND IMMUNOLOGY LAB (4C; 0L+0T+8L)
(Academic Level 300)

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Identify and Analyse different fossils and differentiate between analogous and homologous structures	Analyse
C.O. 2: Differentiate between various developmental stages of frog and chick embryo development	Analyse
C.O. 3: Identify the life stages of important parasites and differentiate between their life stages	Remember and Analyse
C.O. 4: Compare various lymphoid organs and identify different types of blood cells	Analyse

C.O. 5: Apply the techniques of ELISA and immunoelectrophoresis for the identification of various proteins and peptides	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		1					
CO2	3	2						
CO3	2	2	1		1			
CO4	2	1	1			1		
CO5	2	2	1				1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

LIST OF PRACTICAL

1. Study of life stages of *Entamoeba histolytica, Giardia intestinalis, Trypanosoma gambiense, Leishmania donovani* and *Plasmodium vivax* through permanent slides/microphotographs.
2. Study of adult and life stages of *Fasciolopsis buski, Schistosoma haematobium, Taenia solium* and *Hymenolepis nana* through permanent slides/microphotographs.
3. Study of adult and life stages of *Ascaris lumbricoides, Ancylostoma duodenale, Wuchereria bancrofti* and *Trichinella spiralis* through permanent slides/microphotographs.
5. Study of *Pediculus humanus* (Head louse and Body louse), *Xenopsylla cheopis* and *Cimex lectularius* through permanent slides/ photographs.
6. Demonstration of lymphoid organs.
7. Histological study of the spleen, thymus and lymph nodes through slides/photographs.
8. Preparation of stained blood film to study various types of blood cells.
9. Basic patterns of precipitation by Ouchterlony's double immuno-diffusion method.
10. ABO Blood group antigen determination by haemagglutination.
11. Cell counting and viability test from splenocytes of farm-bred animals/cell lines.
12. Demonstration of (a) ELISA (b) Immunoelectrophoresis
13. Detection of complement activity using haemolysis of antibody-coated SRBC and standard serum

24-811-0604 BASIC SKILLS OF COMPUTATIONAL BIOLOGY (3C; 3L+0T+0P) (Academic Level 200)

Course description: This course introduces the fundamental concepts and practical skills required to utilize computational tools for analysing biological data. Through lectures, discussions, coding exercises, and tutorials, the students will explore how computational biology bridges the gap between biology and computer science. The course introduces students to the power of molecular visualization tools and their applications in various biological disciplines.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Understand the vast amount and diverse nature of biological data generated by high-throughput sequencing	Understand

C.O. 2: Develop basic programming skills using a scripting language	Apply
C.O. 3: Develop a problem-solving approach to analyse biological data using computational methods.	Understand
C.O. 4: Explore the role of computational tools in analysing biological structures	Analyse
C.O. 5: Interpret and visualize biological data using computational tools.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	2					
CO2	2			2	1			
CO3	2				2	2		
CO4					2	2	2	
CO5						2	1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Introduction to computational biology: Big data in biology: Genomics, Transcriptomics, Proteomics, etc. Basic principles of computer science relevant to biology: Algorithms, data structures, data types, programming concepts. Overview of major bioinformatics databases and online resources.

MODULE II: Introduction to programming: Programming languages and types, Learning the basics of a scripting language like Python (syntax, data types, loops, functions). Working with biological data in Python: reading, manipulating, and visualizing data. Automating common tasks in data analysis using scripts.

MODULE III: Sequence analysis techniques: Introduction to the world of biological sequences, Sequence similarity searches and interpreting the data, Introduction to sequence alignments and standalone packages for sequence alignments. Sequence submission portals, gene ontology and annotations

MODULE IV: Structural proteomics: Protein folding problems, methods of sequence-based protein structure predictions, understanding protein function using sequence and structure analysis, Protein-protein interaction prediction tools and their applications

MODULE V: Data Visualization and Communication: Understand the importance of molecular visualization in biological research, Introduction to molecular visualization tools, Visualizing protein structure and function prediction methods, Online modelling servers and applications.

REFERENCES

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- Lesk, A. (2014). Introduction to Bioinformatics. United Kingdom: OUP Oxford.
- Hagen, H. (2007). Visualization in Medicine and Life Sciences. Germany: Springer Berlin Heidelberg.

- Introduction to Biological Data Analysis in Python. (2023). (n.p.): Stilianos Louca.
- Via, A., Rother, K., Tramontano, A. (2014). Managing Your Biological Data with Python. United Kingdom: Taylor & Francis.
- Bioinformatics, Fifth edition: Methods and Applications - Genomics, Proteomics and Drug Discovery. (2022). (n.p.): PHI Learning Pvt. Ltd.
- Tramontano, A. (2018). Introduction to Bioinformatics. United Kingdom: CRC Press.

24-811-0605- PLANT PHYSIOLOGY AND BIOCHEMISTRY (4C; 4L+0T+0P) (Academic Level 300)

Course description: The course aims at making students realize how plants function, namely the importance of water, minerals, hormones, and light in plant growth and development; understand transport mechanisms and translocation in the phloem, and appreciate the commercial applications of plant physiology. The course also highlights the importance of secondary metabolites and nitrogen fixation.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O.1: Describe the importance of physical theories for maintaining the physiology	Understand
C.O.2: Differentiate biodiversity based on morphology, anatomy, cell structure and biochemistry with plant functioning.	Analyse
C.O.3: Explain the significance and transportation of mineral nutrition with respect to plants.	Understand
C.O. 4: Apply the knowledge of plant hormones for crop improvement in plant biotechnology	Apply
C.O. 5: Discuss the process of photosynthesis and the rate-limiting steps	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2	2						
CO3	2							
CO4	2		2	2	2			
CO5				1	2			

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- Physiology: General Introduction on physiological processes, their significance and applications, Water relations of plants, physical aspects of absorption-imbibition, diffusion and osmosis. Water potential and osmotic potential, Plasmolysis and its significance, Mechanism of water absorption-active and passive absorption, root pressure, aquaporins. Pathway of water across root cells, Ascent of sap-vital and physical theories. Transpiration-cuticular, lenticular and stomatal. Mechanism-theories -starch sugar hypothesis, potassium -ion theory. Significance of transpiration, anti-transpirants, Guttation and its significance.

MODULE II-Mineral nutrition: Gross chemical analysis of the plant body, ash analysis, criteria for the essentiality of elements, macro and microelements, the role of essential elements and their deficiency symptoms. Culture methods-sand culture, hydroponics and aeroponics. Mechanism of mineral absorption (a) passive absorption-ion exchange and Donnan equilibrium (b) active absorption -carrier concept, Lundegardh hypothesis, Translocation of solutes: Pathway of movement, phloem transport, mechanism of transport-Munch hypothesis, protoplasmic streaming theory-activated diffusion hypothesis, electro-osmotic theory.

MODULE III- Plant movements: Tropic and nastic movements. Circadian rhythm and biological clock. Stress Physiology: Types of stress- water, temperature, salt, stresses caused by pests and pathogens and pollutants, Plant defense systems and mechanisms. Growth regulators-Auxins, Gibberellins, Cytokinins, Ethylene, Abscisic acid-synthetic plant hormones-practical applications. Senescence and abscission. Photoperiodism. Vernalization, Dormancy.

MODULE IV- Photosynthesis, structure and function of the chloroplast, Fluorescence and phosphorescence, Red drop, Emersion effect; Two pigment systems; Mechanism of photosynthesis-Light reaction, Calvin cycle; comparative study of C3, C4 and CAM plants; photorespiration, Factors affecting photosynthesis-Law of limiting factor, Respiration Energy relation of respiration-RQ and its significance-Factors affecting respiration.

MODULE V-Secondary Metabolites and Nitrogen Fixation: Types, structure, functions, Biosynthesis of Secondary metabolites, economic importance. Plants and Nitrogen: The nitrogen cycle, Nitrogen metabolism: Source of nitrogen, Biological nitrogen fixation-symbiotic and asymbiotic. Nitrogen fixation by blue-green algae-rotation of crops. Genetics of N fixation - Nif genes and Leghaemoglobin. Biosynthesis of amino acids- reductive amination and transamination. GDH and GS/ GOGAT pathway.

REFERENCES

1. Dayananda B, 1999. Experiments in Plant Physiology. Narosa Publishing House, New Delhi.
2. Taiz L, Zeiger E, 2023. Plant Physiology and Development (7th Edn). Panima publishing Corporation, New Delhi.
3. Hopkins W G, Norman P A Huner, 2008. Introduction to plant physiology. John Wiley and sons. New York.
4. Jain J L, Sanjay Jain, Nitin Jain, 2005. Fundamentals of Biochemistry. S Chand, New Delhi.
5. Lehninger A L, 1975. Biochemistry. Lalyan publishers, Ludhiana.
6. Nelson D L, Cox M M, 1993. Principles of Biochemistry. MacMillan Publications.
7. Pandey S N, Sinha B K, 2006. Plant Physiology. Vikas Publishing House Pvt. Ltd.
8. Srivastava H S, 2005. Plant Physiology. Rastogi publications, Meerut.
9. Verma V, 2007. Textbook of Plant Physiology. Ane Books India, New Delhi.

24-811-0606 ECONOMIC BOTANY (4C, 4L+0T+0P) (Academic Level 300)

Course Description: This course explores the economic significance of plants, focusing on their uses, cultivation, conservation, and commercial applications. Through theoretical knowledge and practical examples, students will gain insights into the historical, cultural, and contemporary aspects of economic botany, with an emphasis on sustainable utilization and management of plant resources.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O.1: Understand the historical development and theoretical foundations of economic botany.	Understand
C.O.2: Identify and classify economically important plant species and their products and explore the cultural, social, and economic significance of plants in human societies.	Analyse
C.O.3: Examine the principles and practices of plant cultivation, breeding, and domestication for economic purposes and analyse the impact of human activities on plant biodiversity and conservation strategies.	Analyse
C.O. 4: Evaluate the role of plants in providing food, medicine, fibres, dyes, and other commercial products.	Apply
C.O. 5: Develop an understanding of sustainable practices in plant resource management and utilization and apply economic botany principles to real-world scenarios and case studies.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2							
CO3	2							
CO4		2	1					
CO5							1	1

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: **Origin of Cultivated Plants**-Concept of Centres of Origin, their importance with reference to Vavilov's work examples of major plant introductions; Crop domestication and loss of genetic diversity; evolution of new crops/varieties, importance of germplasm diversity.

MODULE II: **Cereals-** Wheat and Rice (origin, morphology, processing & uses), a brief account of millets. **Legumes-** General account, importance to man and ecosystem. **Sugars & Starches**- Morphology and processing of sugarcane, products and by-products of the sugarcane industry. Potato – morphology, propagation & uses.

MODULE III- **Spices**- Listing of important spices, their family and part used, economic importance with special reference to fennel, saffron, clove and black pepper. **Beverages**- Tea, Coffee (morphology, processing & uses). **Oils & Fats**- General description, classification, extraction, their uses and health implications groundnut, coconut, linseed and Brassica and Coconut (Botanical name, family & uses)

MODULE IV- **Essential Oils**- General account, extraction methods, comparison with fatty oils & their uses. **Natural Rubber-** Para-rubber: tapping, processing and uses. **Drug-yielding plants**- Therapeutic and habit-forming drugs with special reference to Cinchona, Digitalis, Papaver and Cannabis.

MODULE V- **Tobacco**- Tobacco (Morphology, processing, uses and health hazards). **Timber plants**- General account with special reference to teak and pine. **Fibres** Classification based on the origin of fibres, Cotton and Jute (morphology, extraction and uses)

REFERENCES
1. Economic Botany- A comprehensive study by S L Kochhar, Fifth Edition(2016), Cambridge University Press, UK
2. A Text Book of Economic Botany by V Verma, (2009)Anne Books Pvt Ltd, New Delhi
3. Economic Botany: Principles and Practices by G.E. Wickens (2012) Kluwer Academic Publishers, New York

24-811-0607 MEDICINAL BOTANY (4C, 4L+0T+0P) (Academic Level 300)

Course Description: This course explores the medicinal properties of plants, focusing on their botanical sources, active constituents, pharmacological actions, and therapeutic applications. Through lectures, laboratory demonstrations, and fieldwork, students will gain insights into the diverse range of medicinal plants, their traditional uses, modern pharmacology, and implications for healthcare and drug discovery.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O.1: Understand the chemical composition and pharmacological properties of medicinal plants.	Understand
C.O.2: Explore traditional and contemporary uses of medicinal plants in healthcare systems worldwide.	Understand
C.O.3: Analyse the role of medicinal botany in drug discovery, pharmaceutical industry, and alternative medicine.	Analyse
C.O. 4: Develop practical skills in the collection, identification, processing, and preparation of medicinal plants.	Apply
C.O. 5: Appreciate the cultural, historical, and ethical dimensions of medicinal botany and herbal medicine.	Understand/Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	3							
CO3	2	2		1				
CO4			2	1	1			
CO5					2	2	1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: **Introduction to Medicinal Botany**- Definition and scope of medicinal botany. Historical perspectives on medicinal plants and herbal medicine. Importance of medicinal plants in traditional and modern healthcare systems

MODULE II: **Botanical Sources of Medicinal Plants**- Classification and identification of medicinal plant families and species. Plant parts used in herbal medicine: roots, leaves, flowers, seeds, and fruits. Botanical gardens and herbaria: resources for studying medicinal plants

MODULE III: **Phytochemistry of Medicinal Plants**- Secondary metabolites in plants: alkaloids, glycosides, terpenoids, and phenolics. Chemical composition and bioactive compounds in medicinal plants. Methods of extraction, isolation, and characterization of plant constituents**.** **Pharmacology of Medicinal Plants-** Pharmacokinetics and pharmacodynamics of herbal remedies**.** Mechanisms of action and therapeutic effects of medicinal plants**.** Safety, toxicity, and adverse effects of herbal products

MODULE IV: **Traditional Medicine Systems**- Traditional healing practices and indigenous medicine systems. Ayurveda, Traditional Chinese Medicine (TCM), Unani, and other traditional systems. Ethnobotanical studies and documentation of traditional knowledge. **Plant Conservation and Sustainable Harvesting-** Conservation status of medicinal plants: threats and conservation strategies**.** Sustainable harvesting practices and cultivation of medicinal crops**.** Certification schemes and ethical sourcing of medicinal plants

MODULE V: **Therapeutic Applications of Medicinal Plants**. Herbal remedies for common ailments: digestive disorders, respiratory infections, skin conditions, etc. Phyto-therapy in chronic diseases: cardiovascular disorders, diabetes, cancer, etc. Herbal preparations: decoctions, infusions, tinctures, extracts, and essential oils. **Modern Applications and Research in Medicinal Botany.** Role of medicinal plants in drug discovery and development Pharmaceutical industry and herbal medicine: challenges and opportunities Clinical trials and evidence-based medicine in herbal therapeutics

REFERENCES

1. Medicinal Plants: Properties, Uses and Production (2021) D. K. Semwal
2. Medical Botany: Plants Affecting Human Health by Memory P. F. Elvin-Lewis; Walter H. Lewis.
3. A Handbook of MEDICINAL PLANTS - A Complete Source Book (2012) edited by Prajapati, Sharma, Kumar, Purohit
4. Relevant research and review articles

24-811-0608- HUMAN PHYSIOLOGY AND ENDOCRINOLOGY (4C; 4L+0T+0P) (Academic Level 300)

Course description: The students will be introduced to the principles of normal biological function in the human body. Basic human physiology will be outlined and correlated with histological structures. The course also provides students with a basic understanding of human endocrine glands, neuro-endocrine glands and their structure, function and signalling pathways. Students will also study the influence of biological rhythm on hormone secretion.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O.1. Explain the principles of normal biological function in the human body.	Understand
C.O.2. Compare histological structures with their function	Analyze
C.O.3. Discuss how animals maintain an internal homeostatic state in response to changes in their external environment.	Understand
C.O. 4. Describe the endocrine system and the basic properties of hormones.	Understand
C.O. 5. Gain insight into the molecular mechanism of hormone action and its regulation.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	3	2						
CO3	2							
CO4	2							
CO5	2							

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Nutritional physiology: Structure and digestive system: General introduction, types of nutrition, mechanical and chemical changes of food in the alimentary canal, balanced diet, nutritional disorders-PEM, vitamin and mineral deficiency, hormonal control of digestion Circulatory physiology: Structure of heart, Blood composition and functions of blood plasma and formed elements, blood groups, mechanism of blood clotting, intrinsic and extrinsic pathways, disorders of blood clotting, anticoagulants, heartbeat, conducting system and pacemaker, pulse and blood pressure, clinical significance, control of cardiac activity, common cardiovascular diseases-arteriosclerosis, atherosclerosis, myocardial infarction, electrocardiogram, angiogram, angioplasty, Lymph and lymphatic system.

MODULE II- Respiratory physiology: Structure of lungs. Gas exchange, respiratory pigments-structure of haemoglobin, transport of oxygen-Oxyhaemoglobin curve, Bohn effect, transport of CO_2-carbonic acid, carbamino haemoglobin, bicarbonate and chloride shift, carbon monoxide poisoning, bronchitis, asthma, physiological effects of smoking, fibrosis
Renal Physiology: Structure of kidney. Nephron-structure, urine formation, counter current multiplier system, the role of the kidney in osmoregulation, renal disorders-nephritis, haematuria, renal calculi, acidosis, and alkalosis-, fibrosis, Dialysis and kidney transplantation

MODULE III- Muscle Physiology: Brief account of types of muscles, fast and slow twitch muscles, red and white muscles, the ultrastructure of striated muscle fibre, muscle proteins, simple muscle twitch, summation, tetanus, tonus, ALL or None Law, fatigue, oxygen belt, rigor mortis, physiological and biochemical events in muscle contraction.
Sensory physiology: Structure of eye and ear. Physiology of vision, visual elements and pigments, photochemistry of vision. Eye defects-myopia, hyperopia, presbyopia, astigmatism, cataract. Structure of ear and mechanism of hearing, hearing impairments-deafness, labyrinthine disease. olfactory, gustatory and tactile sense organs.

MODULE IV-Nerve Physiology: Structure of brain, Neurons-structure, types of neuron. Synapse and types of synapse, nerve impulse propagation, synaptic transmission. Reflex action, refractory period, neurotransmitters, electro encephalogram. Nerve disorders- epilepsy, Alzheimer's disease, Parkinson's disease

MODULE V- Endocrinology: Definition, classification and characteristics of chemical messengers (hormones, neurohormones, neurotransmitters, cytokines, pheromones), Hormone delivery: Endocrine, paracrine and autocrine modes, Hormone feedback mechanisms, Structure and functions of: Pituitary, Thyroid, Parathyroid, Adrenal, Endocrine pancreas, Testis, Ovary, Endocrine glands in insects, Pars Intercerebralis-corpus cardiacum-corpus allatum complex, Prothoracic glands, endocrine disorders.

REFERENCES

1. Best and Taylor. (1990). Physiological basis of Medical Practice. Wilkins Co.

2. Eckert, R. and D. Randell. (1987). Animal Physiology, CBS Publishers and Distributors N. Delhi.
3. Ganong, W.F. (2003), Review of Medical Physiology, McGraw Hill, New Delhi.
4. Guyton, A.C. (1981). Textbook of Medical Physiology, W.B. Saunders Co.
5. Hoar, W.S.(1975). General and Comparative Physiology, Prentice-Hall.
6. Mac. Eleroy, W.D. (1971). Cell Physiology and Biochemistry. Prentice-Hall of India Ltd.
7. Nagabhushanan, R., Kaobarkar M.S. and Sarojini, R. (1983). A textbook of animal physiology, Oxford IBH Publishing Co., New Delhi.
8. Prosser, C.L. (1978). Comparative animal physiology. W.B. Saunders Co.
9. Rama Rao, V., First aid in accidents, Srikrishnan Brothers, Thambuchetty Street, Madras.
10. Schmidt-Nielson K. (2002). Animal Physiology, Prentice Hall India Ltd.
11. Sebastian, M.M. Animal Physiology. Dona Publications, Changanacherry.
12. Norris: Vertebrate Endocrinology, Fourth Edition, 2007, Academic Press

24-811-0609- ECONOMIC ZOOLOGY (4C; 4L+0T+0P) (Academic Level 300)

Course Description: This course explores the economic significance of animals in various aspects of human life, including agriculture, medicine, industry, and conservation. Students will examine the role of animals in providing food, fibre, and other resources, as well as their impact on human health, the economy, and the environment.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O.1. Understand the economic importance of animals in agriculture, medicine, industry, and conservation.	Understand
C.O.2. Identify different animal species and their contributions to human society.	Apply
C.O.3. Analyze the impact of human activities on animal populations and ecosystems.	Analyze
C.O. 4. Explore strategies for sustainable management and conservation of economically valuable species, especially by addressing the local needs	Apply
C.O. 5. Ability for self-employment through pisciculture, diary, silk worm and poultry	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2							
CO3	2						1	
CO4							1	1
CO5						2	1	1

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Insect pests and their economic importance: Common Pests of paddy, Sugarcane, Tea, vegetables and Fruits (Distribution, food plants, life-history, damage caused, prevention and control measures of the Insect pests to be dealt with)

MODULE II: Apiculture: Introduction, species of honey bees, social organisation and life history of honey bees; selection of bees for apiculture, methods of bee keeping (indigenous and modern methods), products of bee keeping (honey and bee wax), bee keeping as an industry.

MODULE III: **Fish and Fisheries**: Culture fisheries: - Introduction to fish culture, types of cultivable species. Freshwater fish culture technique and management of fish culture farm, harvesting and marketing. Capture fisheries: - Commercially important fisheries of Kerala. Fishing tools-crafts and gears. Preservation and processing of fish and fisheries.

MODULE IV: **Poultry**: Introduction, habitat of fowl: food and feeding of fowls- breeds of fowls (indigenous and exotic breeds); eggs and hatching, rearing of chickens; poultry products (eggs and meat); by-products of poultry. **Dairy industry**: Introduction- breeds of dairy animals (cow, buffalo, goat); Milk: processing of milk, marketing and distribution of milk, milk products (Curd, cream, Butter, Ghee, khoya, cheese).

MODULE V: **Sericulture**: Origin and history of the Sericulture Industry in India with special reference to Kerala. Introduction to different silkworms with special reference to Kerala and a brief account of their food plants. Different species of silkworm, their habit and habitat. Types of Cocoon and silk produced by them.

REFERENCES

1. Yadav Manju (2003). Economic Zoology, Discovery Publishing House.
2. Shukla and Upadhyaya (2014). Applied And Economic Zoology, Rastogi Publishers
3. Jabde Pradip V (2005). Textbook of applied Zoology, Discovery Publishing House, New Delhi. Suggested Readings
4. Ahsan Jawaid, Sinha Prasad S. (2000). A handbook on Economic Zoology. S. Chand and Co.

24-811-0610 ANIMAL FORMS AND FUNCTIONS (4C; 4L+0T+0P)
(Academic Level 300)

Course Description: This course aims to provide a thorough knowledge of structural details and a comparative account of the different organ systems of the body from lower to higher vertebrates, and proto-chordate, thus enabling them to appreciate the incredible vertebrate diversity. It helps students propose possible homology between structures and understand how they evolved as the vertebrates dwelled in different habitats. The structural modifications of the digestive, circulatory, respiratory, and skeletal systems relate to the distribution of animals in their different comfort zones of habitat and ecological niches.

Course outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Explain a comparative account of the different vertebrate systems	Understand

C.O. 2: Discuss the structure of respiratory organs used in aquatic, terrestrial and aerial vertebrates; and the digestive system and its anatomical specializations concerning different diets and feeding habits.	Understand
C.O.3: Describe the evolution of the heart, modification in aortic arches	Understand
C.O. 4: Discuss the evolution of the brain, sense organs and excretory organs to a complex, highly evolved form in mammals	Understand
C.O.5: Analyse the structure and functions relationship of animals which furnish with survival advantages in a habitat	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	2							
CO3	2							
CO4	2							
CO5	2							

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I

Modes of Feeding and Digestion: Feeding mechanisms: suspension, deposit, cropping and sucking (herbivorous) and raptorial (carnivorous), Intracellular and extracellular digestion: food vacuole and gastrovascular cavity, Types of excretion and Mode of Excretion Open tubular: metanephridia, Closed saccular: protonephridia, Malpighian tubules and kidney.

MODULE II

Respiratory Organs, Structure and function of gills, trachea, book lungs and vertebrate lungs.

MODULE III

Circulatory systems: Pattern of circulation in non-chordates and chordates, hemocoel, open and closed circulatory systems, the difference in chambers, evolutionary significance.

MODULE IV

Nervous system: Patterns of the nervous system in non-chordates, Organization of the nervous system in vertebrates: central and autonomic system, Receptors and sense organs, Phonoreception in fish and mammals, Photoreception in insects and mammals

MODULE V

Reproduction Types of asexual reproduction: fission, regeneration and parthenogenesis, Sexual reproduction: primary and accessory sex organs and their function

REFERENCES

1. Miller and Harley: Zoology (6th ed. 2005, W.C. Brown)
2. Nigam: Biology of Non-chordates (1997, S Chand)
3. Nigam: Biology of Chordates (1997, S Chand)
4. Parker and Haswell: Textbook of Zoology, Vol. II (2005, Macmillan)
7. Purves et al: Life-the Science of Biology, (7th ed. 2004, Sinauer)
8. Tortora and Anagnostakos: Principles of Anatomy and Physiology (6th ed. 1986, Harper and Row).
9. Schmidt Nielson: Animal Physiology (5th ed. 2005, Cambridge)

SEMESTER VII

SEMESTER VII

24-811-0701- BIOCHEMISTRY (4C; 4L+0T+0P) (Academic Level 300)

Course Description: This course aims to enrich the understanding of the fundamental principles and properties, classification, structure and function significance of biomolecules with a special focus given to enzyme catalysis, kinetics and applications. The course provides application-oriented insights on biochemical techniques involved in characterization, activity studies, structure prediction, and validation of physical, chemical and biological properties of biomolecules. The course covers the methodology and instrumentation aspects of a clinical biochemistry lab. Also introduces the concepts of glycobiology, proteomics and the emerging fields of glycomics and lipidomics.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Understanding the fundamentals of biochemistry	Analyse
C.O. 2: Examine the chemistry of various biomolecules and apply the techniques to identify/purify/predict the structure/synthesise carbohydrates, lipids and their derivatives	Analyse
C.O. 3: Examine the chemical properties and interpret the quantity of various biomolecules and apply the techniques to identify/purify/predict the structure/synthesise proteins and nucleic acids	Analyse
C.O. 4: Investigate the general properties of enzymes using various methods, apply enzyme kinetics to study the nature of enzymes and inhibitors in terms of Km and Vmax Compare the affinity of Enzymes to substrates in terms of Km	Analyse
C.O. 5: Apply the techniques and handle the equipment used in the clinical diagnosis of diseases, Based on theoretical knowledge, set up the working model of a clinical biochemistry lab by a flow chart	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	2	1						
CO3	2	2	1					
CO4			2	1	1			
CO5				1	1	1		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Chemical foundations of life: Overview of weak interactions in aqueous systems, Organic reaction mechanisms (Group-transfer reactions, oxidation and reductions, coupled reactions, Elimination, Isomerization and rearrangements), Thermodynamics of phosphate compounds (Phosphoryl-transfer reactions, High energy compounds and Biological energy transducers (ATP, NADH, NADPH, FADH, CoASH), ATP cycle, structural basis of free energy change during hydrolysis of ATP, High Energy phosphate compounds, Nernst equation and Redox-potentials. Thermodynamics principles in biology and energetics.

MODULE II: Glycobiology and Lipid Biology: Basic structure and reactions and classifications of carbohydrates and lipids, Carbohydrates and lipids as an energy sources, matter and information molecules. Glycoconjugates and their significance, Glycolipids, Carbohydrate based biomaterials and their applications. Techniques of extraction, separation and structure prediction, applications in biomedical sciences, glycomics and lipidomics.

MODULE III: Proteins and Nucleic acids: Chemical, Biological and Physical properties of Protein and nucleotides and types and classification, Structural organization of proteins, Ramachandran Plot, Globular and fibrous proteins, techniques involved in separation, purification, and sequencing and synthesis of peptides/proteins and techniques involved in structure prediction, Proteomics, Protein-ligand interactions and applications in drug development, Structure-activity relationships, and nucleotides as energy and information molecules.

MODULE IV: Enzymes: Examples of Enzymatic reactions, chymotrypsin, hexokinase, enolase etc. Reaction rates and Equilibria, Reaction coordinate diagram, Enzyme substrate complex, mechanisms of catalysis. Enzyme kinetics, Michaelis-Menton Equation, Line weaver burk plots and other representations, enzyme inhibition and allosteric enzymes and bisubstrate reactions. Applications of enzymes, enzyme significance of isozymes in disease diagnosis, enzymes as therapeutic targets and the scope of enzyme engineering.

MODULE V: Clinical Biochemistry- Definition and scope of clinical biochemistry in diagnosis, analyses, collection and preservation of biological fluids (blood, urine & CSF), normal values, reagents for analysis, Requirements of setting up of clinical laboratory, collection preparation, preservation, and handling of clinical samples, quality control, Safety measures in clinical laboratory and practices, common techniques and equipment used in clinical diagnosis of communicable and non-communicable diseases.

REFERENCES

1. Lehninger, A. L., Nelson, David L., Cox, Michael M. (2013).Principles of Biochemistry.6th revised edition
2. Biocatalysis: Biochemical Fundamentals and Applications .2nd reprint Edition. Imperial College Press.
3. Combs Jr, G. F., & McClung, J. P. (2016). The vitamins: fundamental aspects in nutrition and health. Academic press.
4. Lurton, R. (2010).Clinical Biochemistry.2nd Edition. Viva books.
5. White, Abraham. (2004).Principles of Biochemistry.6th edition. Tata Mcgraw-Hill.
6. Cooper T.G. (2015). Tools of Biochemistry.2nd edition, Wiley-Interscience 11. Sadasivam S. and Manickam A.(2009).
7. Biochemical Methods, 2ndedn.New Age International Ltd Publishers.
8. Mu, P., & Plummer, D. T. (1988). Introduction to practical biochemistry. Tata McGraw-Hill Education.
9. Jayaraman J.(1992).Laboratory manual in Biochemistry.John Wiley
10. Enzymes: biochemistry, biotechnology, clinical chemistry. Elsevier. 5. Chaplin, M.F. Buke, C.(1990). Enzyme technology.Cambridge University Press. 6. Grundwald, D. Peter. (2016).
11. Biocatalysis: Biochemical Fundamental and Applications.2nd reprint Edition. Imperial College Press 7. Grunwald, P. (2009).
12. Biocatalysis: biochemical fundamentals and applications. Imperial College Press.

24-811-0702- CELL SIGNALLING AND COMMUNICATION (4C; 4L+0T+0P) (Academic Level 400)

Course Description: Cell Signalling and Communication is a comprehensive course that explores the mechanisms by which cells communicate with each other to coordinate various physiological processes. Students will study the molecular pathways involved in signal transduction, intercellular communication, and the regulation of cellular responses. Emphasis will be placed on understanding the relevance of cell signalling in health and disease.

Prerequisites: Basic knowledge of cell biology and biochemistry.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Understand the fundamental principles of cell signalling and communication	Understand
C.O. 2: Identify and describe the key components involved in signal transduction pathways.	Understand
C.O. 3: Analyse the mechanisms of intercellular communication, including direct and indirect signalling.	Analyze
C.O. 4: Explore the role of cell signalling in development, homeostasis, and disease.	Understand
C.O. 5: Develop critical thinking skills to evaluate experimental evidence and current research in cell signalling.	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	2							
CO3	2	1						
CO4		2	1					
CO5		2	1			1	1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: **Introduction to Cell Signalling-** Overview of cell signalling and its importance Types of signalling molecules: hormones, neurotransmitters, growth factors. Principles of signal reception, transduction, and cellular response. **Signalling Pathways-** Intracellular signalling cascades: cyclic AMP (cAMP), phosphoinositide signalling, kinase cascades G protein-coupled receptors (GPCRs) and their signalling mechanisms Receptor tyrosine kinases (RTKs) and their role in cell growth and differentiation

MODULE II Cell Signalling in Development- Signalling pathways in embryonic development and tissue patterning**.** Role of morphogens and growth factors in cell fate determination**.** Cell signalling in stem cell maintenance and differentiation

MODULE III: Intercellular Communication- Gap junctions and direct cell-cell communication**.** Paracrine and autocrine signalling**.** Synaptic transmission and neurotransmitter signalling**. Signalling and Disease-**Aberrant signalling in cancer: oncogenes, tumour suppressors, and apoptotic pathways**.** Signalling pathways in metabolic diseases: insulin resistance, diabetes Neurodegenerative disorders and synaptic dysfunction

MODULE IV: Signalling in Immune Response-Role of cytokines and chemokines in immune cell communication**.** Signalling pathways in inflammation and immune cell activation**.** Immunotherapy and modulation of immune signalling in disease treatment**. Cellular Communication in the Microenvironment-**Cell-matrix interactions and extracellular matrix signalling**.** Cell adhesion molecules and their role in cell-cell communication**.** Signalling in wound healing and tissue regeneration

MODULE V: **Emerging Topics in Cell Signalling-** Signalling in aging and longevity**.** Computational modelling of signalling networks**.** Single-cell signalling analysis techniques. Advanced Microscopic and flow cytometry techniques, FRET-based assessment of cell signalling, Immune cell sorting and analysis, FISH. Determination of calcium flux, localization and translocation of proteins during various cellular events, tracking of cellular events like apoptosis and autophagy.

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2. Chris A. Kaiser, Kelsey C. Martin, Harvey Lodish, Arnold Berk, Monty Krieger, Anthony Bretscher, Hidde Ploegh, Angelika Amon, Matthew P. Scott Molecular Cell Biology (8th Edition) by, Published by W H. Freeman; 2016
3. Bruce Alberts, Dennis Bray, Karen Hopkin, Alexander D. Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter; Essential Cell Biology (4th Edition) by Garland Science; 2013
4. Gerald Karp, Janet Iwasa, Wallace Marshall; Cell Biology (8th Edition); by Wiley; 2018
5. David E. Sadava; Jones & Bartlett Learning, Cell Biology: Organelle Structure and Function; 1993
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8. Jeff Hardin Gregory Paul Bertoni; Becker's World of the Cell, (9th Edition) by Pearson; 2015

24-811-0703- ADVANCED MICROBIOLOGY (4C; 4L+0T+0P) (Academic Level 400)

Course description: The course aims to understand the advanced biology of bacteria, viruses, fungi and associated pathogenesis in plants and animals. The course also helps gain in-depth knowledge of the microflora in various habitats and environmental conditions and their plausible industrial applications.

Prerequisites: General Microbiology

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O.1: Application of specific molecular markers like 16S rDNA/ 18S rDNA /COXa sequence amplification and analysis for molecular classification of microorganisms	Apply
C.O.2: Construction of phylogenetic tree to understand the relatedness	Analyse
C.O.3: Construct Antibiogram for analysis of the antibiotic profile of given pathogens-Disk diffusion method	Analyse
C.O.4: Quantify the antibiotic sensitivity using liquid assay-MIC	Apply
C.O.5: Amplify the R-gene using PCR techniques, confirm its presence by electrophoresis and analyse the sequence data	Apply & Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2	2					
CO2				1	2	2		
CO3				1	1	2		
CO4			2	1	1			
CO5			2	1	1			

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- Bacteriology: Classification, virulence factors, microbial communication system; bacterial quorum sensing; toxin genes, virulence, Biofilms in disease; Pathogenic bacteria and viruses, AMR genes in pathogenesis, plant diseases, microbial diseases in animals, Human Bacterial diseases-Tuberculosis, leprosy, Cholera, Typhoid, Human microbiota and their role in human health, Drug-resistant bacteria, antibiotics and antimicrobial agents.

MODULE II- Virology: Virus and bacteriophages, Viruses and bacteriophages, general properties of viruses, Viral structure, genetic materials, virulence factors, viral metabolism, reproduction, phages, viral structure, the taxonomy of viruses, viral replication, cultivation and identification of viruses; sub-viral particles–viroids and prions. Viruses, bacteriophages and their applications, Viral diseases: Polio, HIV, Hepatitis, Rabies, Influenza, H1N1, SARS, COVID-19

MODULE III- Mycology: Fungal diseases in plants and animals pathobiology, beneficial fungi, Antibiotic production, antibiotic resistance mechanisms and alternative measures.

MODULE IV- Microbial genetics: Organization of the bacterial chromosome, Regulation of gene expression, Induction, and repression- the lac operon, regulatory mutants of the lac operon. Quorum sensing and cross-talks. Importance and uses of mutation analysis. Isolation and identification of mutants. Extrachromosomal inheritance. Gene transfer and mapping by conjugation, Gene transfer by transformation and transduction, Transposons. Genetics of bacteriophages- lytic and lysogenic cycles

MODULE V- Genetic analysis of bacteria: Gene mapping, conjugational analysis, transformation and transduction, Molecular techniques in gene mapping-gene libraries, Restriction mapping and PFGE, Diagnosis and epidemiology-gene probes for detection of pathogens, Detection of virulence genes; diagnostic use of PCR, molecular epidemiology.

Genetic analysis of Phages – complementation and recombination tests with phages. Genetic experiments with the rII genes of phage T4. Deciphering the genetic code using rII mutants. Constructing phage genetic linkage maps using two-factor and three-factor crosses.
Assays to analyse transposition events – suicide vectors and mating out assays. Transposon mutagenesis, cloning genes by transposon mutagenesis, mini-Mu elements, and their use in *in vivo* cloning.

REFERENCES

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2. Gibson, D. T. (1984). Microbial degradation of organic compounds. Marcel Dekker Inc.
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6. Stanier, R.Y. (1987). General Microbiology, 5th Edition, Prentice Hall Macmillan Education Ltd.
7. White, D. (1996). The physiology and biochemistry of prokaryotes: General Pharmacology.
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9. Marjorie Kelly Cowan (2015). Microbiology: A Systems Approach,3rd edition, McGraw-Hill Higher Education.
10. Booth S J. (2010). Microbiology: Pearls of Wisdom, 2nd edition, Scientific book center.
11. Sherwood, L., Willey, J. M., &Woolverton, C. (2011). Prescott's Microbiology. McGraw-Hill.

24-811-0704- MOLECULAR BIOLOGY (4C; 4L+0T+0P) (Academic Level 400)

Course description: This course is intended to be an advanced course in molecular biology that builds on the basic undergraduate Molecular Biology course. The course is intended to focus more on the fundamental principles of Molecular Biology than the vast information that is there in the field. At the end of the course, students will be able to explain the principles underlying life at a cellular level. They will also be able to design appropriate experiments to test hypotheses regarding the inner workings of a cell. This course will also introduce students to the latest discoveries in the field by way of analysis of original journal articles and presentations by the students.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Describe the fundamental principles of replication and maintenance and gene expression and regulation. in cells	Understand
C.O. 2: Design experimental strategies for testing molecular biological	Analyse

hypothesis	
C.O. 3: Analyse experimental data to explain the reasons for observed changes in gene expression and activity in cells	Analyse
C.O. 4: Select appropriate model systems for studying different molecular biological processes	Analyse
C.O. 5: Analyse and understand journal articles containing original research	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2	1	2					
CO3		2	2			1	1	
CO4					1	1	2	
CO5							1	1

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I

Structure of Macromolecules: Bonds and interactions in Biology; Central Dogma; Structure of DNA and RNA; Denaturation & renaturation of DNA, unique and repetitive DNA sequences (LINEs, SINEs), the 3D structure of proteins, protein folding, Dynamics (Haemoglobin, Myoglobin).

MODULE II

Maintenance of Genome: Genome structure, Chromatin and the Nucleosome; Replication of DNA, Extrachromosomal Replicons; Mutability and Repair of DNA, Homologous Recombination; Site-specific recombination, Transposition of DNA

MODULE III

Transcription and Translation of Genetic Information: Mechanism of Transcription; RNA polymerases in eukaryotes, general and specific transcription factors, assembly of pre-initiation complex, enhanceosomes, elongation factors and elongation; Types of introns and mechanism of splicing. Translation; The Genetic Code.

MODULE IV

Promoter analysis and characterization: Deletion mapping, Transient/stable expression system, S1/RNase mapping, EMSA, DNase I Foot-printing. RNA editing, catalytic RNA; Regulation of initiation of transcription. Control of gene expression: Transcriptional regulation in prokaryotes; Transcriptional Regulation in Eukaryotes. Post-transcriptional gene silencing, RNA Interference. Post-translational modifications

MODULE V

Regulatory RNAs; Gene Regulation in Development and Evolution; Systems Biology; Model Organisms in Molecular Biology (*Saccharomyces cerevisiae Arabidopsis thaliana*, *Drosophila melanogaster*, *Caenorhabditis elegans*, zebrafish, *Mus musculus*).

REFERENCES

1. Molecular Biology of the Gene,7th edition, Watson et al. 2013, CSHL Press (Primary Reference Book)
2. Genes XII, Lewin et. al., 2017, Jones and Bartlett Pub Inc.

3. Molecular Biology of the Cell, Alberts, Bruce, 6th edition, 2014, Garland Pub. Inc.
4. Biochemistry of Nucleic acids, -Roger L. P. Adams et al.,11th edition, 2007, Chapman & Hall
5. Molecular Cell Biology, Lodish, Baltimore, et al., 8th edition, 2016, W.H. Freeman and Co.
6. Molecular Biology and Biotechnology: A Comprehensive Desk Reference, Meyers, Robert A, 2011 ed. Wiley, New Delhi.
7. Molecular Biology –David Clark and Nanette K Pazdernik, 2nd edition,2013, Academic press
8. Selected research papers to be given

24-811-0705- ADVANCED BIOLOGY LAB (4C; 0L+0T+8P) (Academic Level 400)

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O. 1: Evaluate and estimate various biomolecules using standard biochemical techniques	Analyse
C.O. 2: Analyze various organelles of cells using imaging	Analyse
C.O. 3: Identity carbohydrates (sugars), amino acids/proteins, cholesterol and triglycerides and nucleic acids	Analyse
C.O. 4: Apply recombinant DNA technology technique to demonstrate the bacterial transformation in *E. coli*	Apply
C.O. 5: Apply chromatographic and electrophoretic techniques for purification and molecular analysis of the proteins	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2	2	1				
CO2		2	2	1	1			
CO3		2	2					
CO4				1	1	1		
CO5				1	1	1		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

LIST OF PRACTICAL

Biochemistry

1. Qualitative and Quantitative tests for carbohydrates/proteins/lipids and nucleic acids
2. Cholesterol profiling, Liver and kidney function test
3. Enzyme extraction /purification and Assay to determine activity and specific activity
4. Factors affecting enzyme activity/Fluorescence spectroscopy to study the effect of temperature and pH on protein structure
5. Effect on velocity: MM plot and Lineweaver -Burk Plot determination of Km and Vmax
6. Effect of inhibitors on enzyme activity

Cell Biology

1. Cell culture facilities in practice
2. Cell culture in vitro
3. Trypsinisation and methods for detachment of cells
4. Cell counting and reseeding.
5. Cell imaging analysis of marker proteins for visualizing; various organelles, proliferation, apoptosis, cell-matrix, differentiation and proteins involved in signal transduction.
6. Cell cycle stages by FACS analysis
7. Tissue sectioning using a cryostat.
8. Visualization of the processed tissue samples
9. Immunocytochemistry

Molecular Biology

1. DNA and RNA isolation
2. Primer designing
3. PCR and semi-quantitative RT PCR
4. Analysis of PCR products on an agarose gel.
5. Southern/Northern/Western hybridization techniques
6. Restriction digestion and analysis
7. Competent cell preparation and analysis of efficiency

Advanced Microbiology

1. Media preparation, microbial culture (bacterial and fungal).
2. Growth curves, preservation of the bacteria, plating, dilution plating.
3. Effect of temperature, pH, salts and other stress factors on bacterial growth.
4. Isolation of bacteria from various surroundings, Identification of bacteria by biochemical assays and Gram staining.
5. Antibiotic or drug inhibition assays.
6. Transformation and competent cell preparation studying *E. coli* as a model microorganism for R&D.

24-811-10706 OPEN-ENDED LAB (2C; 0L+0T+4P) (Academic Level 400)

Course Description: The Open-Ended Laboratory Exploration course provides students with the opportunity to engage in hands-on scientific inquiry and experimentation. Through a series of open-ended laboratory activities, students will explore various concepts of Biological Sciences, develop experimental skills, and enhance their critical thinking abilities. The course emphasizes creativity, curiosity, and independent problem-solving.

SEMESTER VIII

SEMESTER VIII

BSc HONORS WITH RESEARCH

24-811-0801 MOOC1 (4C; 4L+0T+0P) (Academic Level 300)
24-811-0802 MOOC2 (4C; 4L+0T+0P) (Academic Level 400)
24-811-0803 Project (12C; 0L+0T+24P) (Academic Level 400)

24-811-0804 Review Writing and Seminar (2C; 0L+2T+0P) (Academic Level 400)

BSc HONORS

24-811-0801- CELLULAR METABOLISM (4C; 3L+0T+2P) (Academic Level 300)

Course Description: This advanced course in biochemistry includes the study of metabolic pathways, energetics, regulation of carbohydrates, amino acids, fatty acids, nucleic acids as well as Electron transport chain and Photosynthesis. In addition, the course offers a deep understanding of analysing the energetics of metabolic pathways, interpretation of metabolic syndromes and disorders at clinical point of view, basic concepts to develop diagnostic protocols and therapeutic strategies against metabolic errors. Also provides insights in to predicting metabolic pathways and hub proteins with respect to disease pathogenesis, identification and validation of metabolites as biomarkers.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	**Cognitive Level**
C.O. 1: Compare and contrast biosynthetic and catabolic pathways of carbohydrates based on enzymes involved, intermediates and their regulation Interpret the energetics of carbohydrate metabolic pathways. Interpret the metabolic disorders of carbohydrates and examine how they can be diagnosed clinically	Apply
C.O. 2: Understanding basic metabolic pathways of Lipids and their conjugates Examine the energetics of lipid metabolic pathways. Develop the protocols to interpret the metabolic disorders of lipids and examine how they can be diagnosed clinically	Analyze
C.O. 3: Understanding basic metabolic pathways of Purine and Pyrimidines. Examine the energetics of purine and pyrimidine metabolic pathways. Develop the protocols to interpret the metabolic disorders of purine and pyrimidine and examine how they can be diagnosed clinically.	Analyse
C.O. 4: Understanding basic metabolic pathways of amino acids and proteins. Examine the energetics of protein metabolic pathways. Develop the protocols to Interpret the metabolic disorders of amino acids and proteins and examine how they can be diagnosed clinically.	Analyse

C.O. 5: Interpret metabolic pathways based on proteomics data, Design metabolomic models/protocols to explore novel biomarkers, therapeutic targets and development of therapeutics and diagnostics strategies	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2						
CO2	2	1	2					
CO3		2	2	2				
CO4	2	1						
CO5		2	1			1	1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Overview of carbohydrate metabolism, basic concepts, Glycolysis, Krebs cycle, Electron Transport chain, Photosynthesis, aerobic and anaerobic respiration, ATP synthesis, Energetics, Pentose phosphate pathway, Gluconeogenesis, Glycogenesis, Glycogenolysis, Regulation of carbohydrate metabolism. Inborn errors of carbohydrate metabolism and diagnosis, Galactosemia and Glycogen storage diseases, Metabolic syndrome and life style diseases, Diabetes and Lactose intolerance

MODULE II: Lipid metabolism: Biosynthesis and degradation and regulation fatty acids metabolic pathways, Ketone bodies: formation and utilization. Biosynthesis and degradation and regulation of cholesterol, Eicosanoids biosynthesis, Disorders of Lipids:Clinical features and laboratory findings in disorders of triglyceride, lipoprotein and cholesterol metabolism, lipoprotein and apolipoprotein metabolism; HDL, LDL, VLDL, apoA, apoB, apoC, apoE and their receptors. Fat absorption, transport, storage and metabolism, Investigation and principles of treatment of hyperlipidemia, Inbpre errors of lipid metabolism, lipid storage diseases and diagnosis.

MODULE III: Nucleic Acid metabolism: Biosynthesis and degradation of purines and pyrimidines, regulation of purines and pyrimidines biosynthesis. Biosynthesis of ribonucleotides and deoxyribonucleotides. Uric acid overproduction and underexcretion; pathology and differential diagnosis of gout, treatment of gout, Enzyme disorders of nucleotide metabolism (Lesh-Nyhan syndrome and Orotic acid urea, diagnosis and treatment

MODULE IV: Amino acid metabolism and disorders: Protein degradation and turn over, Amino acid synthesis, Catabolism of amino acid nitrogen - transamination, deamination, ammonia formation; urea cycle, regulation and disorders of amino acid metabolism. Clinical features and laboratory findings in disorders of amino acid protein metabolism, protein misfolding and associated clinical pathogenesis, prion proteins and relevance in neurodegenerative diseases.

MODULE V: Metabolomics and application: Pathway analysis and enrichment by *in-silico* prediction and experimental validation, Networks and interactions between metabolites, pharmaceuticals, SNPs and Proteins, techniques of Metabolic profiling and fingerprinting and their applications, diagnosis of metabolic genetic diseases and syndrome, metabolite target analysis, metabolic applications within animals, plants and microbes, transcriptomics and proteomics in system biology and synthetic biology.

Suggested Practical

1. Estimation of carbohydrates (Sugars), proteins, cholesterol and triglycerides and nucleic acids by spectroscopic analysis
2. Basic metabolic panel: Clinical biochemical tests for glucose, calcium, electrolytes and Liver function and Kidney function test
3. Chromatographic Techniques to study metabolic intermediates
4. Fluorescence spectroscopy to study ligand-protein interaction
5. Proteomics Data analysis, *In-silico* prediction of metabolic pathways, hub proteins,
6. In silico system biology model development, development of metabolic prediction models.

REFERENCES

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5. Harper's illustrated biochemistry (2015) Peter J. Kennelly, Kathleen M. Botham, Owen P. McGuinness, Victor W. Rodwell, P. Anthony Weil
6. Metabolomics: Methods and Protocols, Weckwerth, Wolfram (2014)
7. Metabolomics: A powerful tool in systems Biology (2007) Jens Nielsen, Michael C. Jewett

24-811-0802 BIOSTATISTICS AND BIOINFORMATICS (4C; 3L+0T+2P)
(Academic Level 400)

Course description: This course offers an overview of the fundamental concepts of Biostatistics and Bioinformatics. An interdisciplinary program, it emphasizes the integration of Computer Science with Biology and introduces the students to various computational methods and software tools based on biostatistics for understanding biological databases, gene sequence alignments, gene annotation, protein structure predictions, drug discovery, molecular phylogeny, metagenomics, etc.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	Cognitive Level
C.O.1: Understand and interpret commonly reported statistical measures in Biological science and perform basic statistical analyses such as hypothesis testing and estimation	Apply
C.o.2: Measure variability (standard deviation, standard error, co- efficient of variance) and hypothesis testing (Z-test, t-Test, chi-square test)	Apply
C.O. 3: Describe theoretical sources of biological data, and list various biological databases – nucleic acids, protein sequence, metabolic pathways and small molecule	Understand

C.O. 4: Identify various file formats of sequence data and tools for submission of data in databases as well as retrieval of gene and protein data from databases	Understand
C.O. 5: Apply various computational tools and methodologies and their application in structural bioinformatics, functional genomics and in silico drug discovery.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	2	1	2					
CO3	2	2						
CO4		2	1	1				
CO5		1	2	1	1			

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Introduction to Biostatistics: Variable and attribute; Population *vs.* Sample; Arrangement of data; Frequency distribution. Graphical presentation of data: Line diagram; Bar diagram; Pie chart; Histogram. Measures of central tendency: Arithmetic mean; Mode; Median.

MODULE II: Measures of dispersion: Variance; Standard deviation; Standard error of the mean; Testing of hypothesis and goodness of fit: Null hypothesis, Level of significance, Probability, Normal distribution, Error of inference, Student's t-test, Chi-square test.

MODULE III: Overview of Information Technology: features of the modern Personal Computer and Peripherals computer networks and Internet. Introduction to Operating System. DOS/Windows. Linux. Purchase of technology, license. guarantee. warranty. Definition, Nature & Scope of Bioinformatics.

MODULE IV: Computational Biology; Key Bio-sequences in Molecular Biology - DNA, RNA and Amino acid sequences. Popular Databases in Bioinformatics – NCBI, DDJB, PDB, OMIM; BLAST & FASTA sequence file formats.

MODULE V: Approach of Comparative Biology based on sequence comparison - The basic idea of sequence comparison (algorithms not required) - idea of scoring matrices. The BLAST search engine and types of BLAST- important features- Multiple sequence alignment and phylogenetic analysis). Basic concepts of computer aided drug discovery. Basic concepts of protein structure prediction. Introduction to Comparative Genomics.

Suggested Practical

1. To perform a “two-sample t- test” for a given set of data
2. To learn graphical representations of statistical data with the help of computers (e.g. MS Excel).
3. Accessing different biological databases
4. Retrieval of nucleotide and protein sequences from the databases.
5. To perform pair-wise alignment of sequences (BLAST) and interpret the output
6. Generation of a phylogenetic tree and its analysis
7. Translate a nucleotide sequence and select the correct reading frame of the polypeptide from the output sequences

8. Predict the structure of a protein from its amino acid sequence.
9. Homology-based protein structure prediction

REFERENCES

1. Norman, T.J. Bailey (2007) Statistical methods in biology, 3rd edition. Cambridge university press.
2. Sokal & Rohif(1973) Introduction to Biostatistics -Toppan Co-Japan
3. Veerbala Rastogi. (2008) Fundamentals of biostatistics. Ane booksindia. Chennai.
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11. Graeme. D. Ruxton and Nick Colegrave. (2006) Experimental design for the life sciences, 2nd edition. Oxford University press.
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24-811-0803- MINI PROJECT (4C; 0L+0T+8P) (Academic Level 400)

24-811-0804- CRITICAL ANALYSIS OF CLASSICAL PAPERS (2C; 2L+0T+0P) (Academic Level 400)

Course Description:
This course aims to equip students with essential skills in effectively communicating scientific concepts and critically analysing research literature. Through interactive lectures and paper presentations, the students will learn how to articulate complex ideas with clarity and precision, while also improving their ability to evaluate the validity, reliability, and significance of research findings. Each week, two-hours will be dedicated to this course, during which each student is given the opportunity to present a research paper of their interest and follow it up with a group discussion with their classmates and teachers. By the end of the course, students will have developed the proficiency to craft well-structured scientific reports, deliver compelling presentations, and engage in insightful discussions on contemporary scientific issues, thus empowering them to excel in both academic and professional settings.

Course Outcomes (CO) After completing the course, the student will be able to:

Course Outcome		Cognitive Level
C.O.1.	Appreciate the path-breaking work published in research papers	Understand

C.O.2.	Apply data analysis tools and logical reasoning in the in-depth study and critical analysis of primary literature data	Apply
C.O.3.	Generate hypothesis from primary literature and anecdotal data	Analyse
C.O.4.	Ability to effectively summarize a compendium of research work or information	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	2	1				1	1	
CO3				2	1			
CO4							1	2

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Source of Scientific Information: Journals (current and back volumes): Indexing journals, abstracting journals, research journals, review journals, e-journals; Impact factor; NCBI-Pub Med., Data Bank and Data Mining; INFLIBNET, INSDOC.

MODULE II: Scientific communication - Writing: Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non-blind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.

MODULE III: Student presentations
Guidelines for selecting research papers for presentation:

1. Impact factor: Research papers selected for presentation should have an Impact Factor exceeding 5, ensuring the inclusion of high-quality, influential studies that have made significant contributions to their respective fields.
2. Citation metrics: Preference should be given to papers with a substantial number of citations, indicating widespread recognition and influence within the scientific community. Papers demonstrating robust citation metrics serve as reliable indicators of their importance and relevance in the field.
3. Relevance and timeliness: Papers should be selected based on their relevance to current research trends and emerging topics within the discipline. Emphasis should be placed on choosing papers that address timely issues and contribute to advancing knowledge in key areas of interest.
4. Rigorous peer review: Papers undergoing rigorous peer review processes, preferably from reputable publishers/journals (Springer, John Wiley & Sons, Taylor & Francis, Elsevier etc), with stringent editorial standards, should be prioritized. This ensures the integrity and reliability of the research findings presented, enhancing the credibility of the selected papers.
5. Contribution to advancing knowledge: Selected papers should represent significant advancements or breakthroughs in their respective fields, offering novel insights, innovative methodologies, or transformative outcomes that contribute to the advancement of scientific knowledge and understanding.

General guidelines for paper presentation:

1. A total duration of 40 minutes, with an additional 20 minutes designated for interactive discussion, is allocated for each student presentation.
2. Adherence to the assigned time limit is strongly encouraged to ensure effective time management during the presentation session.
3. The presenting student is required to submit a concise summary (1-2 pages) of the research paper of their choice one-day prior to their presentation.
4. Other students in the batch are required to submit their summaries within two days following the presentation.
5. Students are urged to utilize the subsequent assessment criteria as a reference while preparing for their presentations, as they will be evaluated based on the following marking pattern.

Criteria	**Maximum Marks**
The Standard and Quality of the paper selected	20
Presentation, Delivery, and Time management	30
Subject Knowledge/ Answering Questions	20
Summary writing	10
Overall quality	20
Total	100

24-811-0805- ANALYTICAL TECHNIQUES (4C; 4L+0T+0P) (Academic Level 400)

Course Description: Analytical Techniques in Biological Sciences is designed to provide students with a comprehensive understanding of the various analytical methods and instruments used in the field of biology. The course will cover theoretical principles, practical applications, and hands-on experience with a variety of techniques commonly employed in biological research. Emphasis will be placed on the critical evaluation of data and the selection of appropriate analytical methods for specific biological questions.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcome	**Cognitive Level**
C.O. 1: Introduce students to the fundamental principles underlying analytical techniques in biological sciences.	Understand
C.O. 2: Familiarize students with a range of analytical methods used for the study of biological systems.	Understand
C.O. 3: Provide students with practical skills in using laboratory instruments and equipment for biological analysis.	Remember and Apply
C.O. 4: Develop students' ability to interpret and critically evaluate data obtained from analytical techniques.	Apply
C.O. 5: Enable students to design experiments and select appropriate analytical methods for specific research questions in biology.	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	2							
CO3	2	2	1					
CO4		2	1					
CO5			2	1	1	1		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Introduction to Analytical Techniques in Biology- Overview of analytical methods. Importance of analytical techniques in biological research. **Spectroscopic Techniques**- UV-Visible Spectroscopy, Fluorescence Spectroscopy, Infrared Spectroscopy Nuclear Magnetic Resonance (NMR) Spectroscopy, FTIR, Raman Spectroscopy. Principles of Mass Spectrometry

MODULE II: Chromatographic Techniques- Planar chromatography: Paper and Thin-layer chromatography Gas Chromatography (GC), Liquid Chromatography (LC), High-Performance Liquid Chromatography (HPLC), Thin-Layer Chromatography (TLC). **Molecular Techniques**: Types of PCR: multiplex, nested; reverse-transcription PCR, real-time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, ARMS; ISH; FISH; ISA; RFLP; DHPLC; DGGE; CSCE; SSCP; Nucleic acid sequencing: new generations of automated sequencers; Microarray chips; microarray: 16S rRNA typing; EST; SAGE; Blotting techniques - Southern, Northern

MODULE III: Electrophoretic Techniques- General principles, electrophoresis of nucleic acids: Agarose, pulse-field and sequencing gels, Capillary electrophoresis, Single-molecule electrophoresis. Electrophoresis of proteins: SDS-PAGE, native gels, gradient gels, isoelectric focusing, two-dimensional gels, gel-free protein electrophoresis

MODULE IV: Microscopic Techniques-Light microscopy; lenses and microscopes, refractive index, magnification, resolution: Rayleigh's Approach, Dark-field; Phase Contrast, Differential Interference Contrast; Fluorescence microscopy; Confocal microscopy; Electron microscopy: TEM and SEM. Super-Resolution Imaging with Stochastic Optical Reconstruction Microscopy (STORM) and Photoactivated Localization Microscopy (PALM), Atomic Force Microscopy (AFM).

MODULE V: Centrifugation: Basic principles of sedimentation, Types of centrifuges: Micro centrifuge, High speed & Ultracentrifuges; Types of rotors, Preparative and analytical ultracentrifugation methods; preparative centrifugation; differential and density gradient centrifugation; analytical centrifugation; Determination of molecular weight by sedimentation velocity & sedimentation equilibrium methods.

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24-811-0806- CANCER BIOLOGY (4C; 4L+0T+0P) (Academic Level 400)

Course Description: This course aims to provide an inclusive outline of the biology and pathology of cancer by exploring the role of mutations, and dysregulated signalling pathways in cell survival, apoptosis, cell cycle regulation, angiogenesis, metastasis and cancer stemness. The course enriches the basic principles of diagnostics and therapeutic strategies for cancers. In addition, it fosters a deeper insight into techniques to unravel the mechanisms of cancer evolution.

Course Outcomes (CO): After completing the course student will be able to

Course outcomes		**Cognitive level**
C.O.1	Understanding the fundamentals of carcinogenesis	Understand
C.O.2	Understand the basic principles of genetics and epigenetic changes associated with carcinogenesis and demonstrate the methods to identify genetic and epigenetic changes	Understand
C.O.3	Examine intricate signalling events associated with cancer to interpret receptors, oncogenes and enzymes for developing therapeutics.	Analyse
C.O.4	Investigate the role of various mutations/oncogenes/proteins in determining the angiogenic/metastatic and stemness potential of cancer	Analyse
C.O.5	Apply the techniques to evaluate and identify novel biomarkers and therapeutic targets	Apply

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	2							
CO2	2							
CO3	2							
CO4	2		2	1	1			
CO5			2		1		1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Introduction to cancer, types, etiology and incidence; Causes of Cancer, Types of carcinogens: Chemical, Physical and Biological, cancer as a genetic disease, tumour viruses, Oncogenes and tumour suppressor genes, Oncogenesis, immune evasion mechanisms, Clonal evolution, Stages of carcinogenesis and signalling.

MODULE II: Genetics and Epigenetics aspects of Carcinogenesis - Defects in DNA repair and their link to cancer; Driver and passenger mutations, mutational analysis, genomic instability, heterogeneity, Epigenetic changes in cancer, methylation, Histone Acetylation, Non-coding RNAs, miRNAs in cancer, Cancer metabolism and Warburg effect, Techniques employed to identify non-coding RNA, microRNA and epigenetic changes.

MODULE III: Sustaining proliferative signalling: role of growth factors and receptors, complex signalling enabling enhanced survival, cell cycle deregulation, Major pathways in cancer: Ras, EGFR, Wnt, MAPK, AKT, mTOR, Jak-Stat, etc, anti-apoptotic pathways, Bcl2 family proteins, role of P53, events enabling replicative immortalization, role of telomere, Techniques employed in unravelling survival/ apoptosis/cell cycle machinery.

MODULE IV: Angiogenesis, **Metastasis and Cancer Stem cells**: factors aiding the mechanism of angiogenesis, hypoxia (vegf), metastasis (metalloproteinases, EMT), and cancer stem cell maintenances, side cell population, (stem cell markers and efflux pumps), mechanism of tumour aggression and relapse, Techniques employed to elucidate the mechanism of angiogenesis, metastasis and identification of stem cells.

MODULE V: Diagnosis and Therapeutics of Cancer: Diagnostic techniques and methods, biopsy, histopathology, cytology, FISH, FACS, PET, MRI, CT, mammogram and others; Endoscopy methods, Cancer predisposition, SNPs, RFLP, NGS, Single-cell RNA sequencing, exome sequencing, identification and validation of novel markers and therapeutic targets, cancer treatments, surgery, radiation, chemotherapy, immunotherapy, targeted therapy, and precision medicine.

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24-811-0807- MOLECULAR NEUROBIOLOGY (4C; 4L+0T+0P)
(Academic Level 400)

Course Description: The course structure is aimed at providing in-depth knowledge of molecular and cellular neurobiology by giving emphasis on human neurobiology. The course introduction focuses on neuroanatomy, neurodevelopment, cell types of the nervous system and mechanisms of neural communication. During the later stages of this course, students get a chance to learn about more integrated functions of the nervous system like sensory processing and the programming of motor functions. In addition, students will also get a basic understanding about how new memories are formed, stored, and retrieved in the brain. The course also focuses on the neuroscience of brain diseases and describes the current methods in neuroscience research.

Course Outcomes(CO): After completing the course the student will be able to:

Course outcomes		**Cognitive level**
C.O.1	Demonstrate a solid understanding of basic neuroanatomy and nervous system function on a molecular, cellular and systems level.	Understand
C.O.2	Analyse how neurons are connected and how it communicates in neuronal circuits that control our behaviour.	Analyse
C.O.3	Analyse the functions of the nervous system such as the regulation of sensation, integration and response; with special emphasis on cognitive functions like learning and memory.	Analyse
C.O.4	Understand and Analyse the neurological disorders such as Alzheimer's disease, Parkinson's Disease, Amyotrophic lateral sclerosis (ALS), Huntington's disease, Schizophrenia, psychiatric disorders, Traumatic Brain Injury and Stroke.	Analyse
C.O.5	Analyse the neurobiological techniques, such as brain histology, optogenetics, electrophysiology, CLARITY, behavioural analyses and transgenics, also identify gaps in knowledge and retrieve knowledge independently to be able to present a scientifically sound solution.	Analyse/ Apply

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	2							
CO2		2	2					
CO3		2	2	1				
CO4	2	1						
CO5	2	2		1				

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Organization of the nervous system: Organization of nervous system; CNS, PNS, Neuroanatomy, Meninges, Cerebrospinal fluid, Blood Brain Barrier, Neuron structure and classification, Glial cells: Structure and function of glial cells, Glial – Neuronal interplay, Neurotrophic factors, Neurogenesis; Birth and migration of neurons, Neural stem cells, Brain changes across the lifespan.

MODULE II: Propagation of nerve impulses and molecular mechanisms of neurotransmission: Biological and electrical properties of neurons, Ionic Basis of the Resting Membrane Potential, Ionic Basis of the Action Potential, Molecular Mechanisms of Action Potential Generation, Propagation of Action Potentials, Synaptic Transmission, Neurotransmitters; chemistry, synthesis, storage, release and uptake, Ionotropic Neurotransmitters Receptors, Metabotropic Neurotransmitters Receptors and Postsynaptic Mechanisms, Synaptic Integration, Long-Term Potentiation and Depression, Spike-Timing Dependent synaptic Plasticity, Hebb's Postulate

MODULE III: Neural Control Systems: Sensory Systems; The Visual System, Audition, Vestibular Sensation and Chemical Senses, Movement and Motor Control, Neural control of; Immune, Cardiovascular, Endocrine and Enteric nervous systems

MODULE IV: Complex Brain Functions and Brain Disorders: Circadian Rhythms, Sleep; Brain Waves and Sleep Stages, Neurobiology of Emotion, Reward and Addiction, Learning and Memory; Cognitive development, Visual Recognition, Language, Short-term, long-term and Working Memory.
Neurodegenerative disorders; Alzheimer's, Parkinson's, Huntington's and Prion Diseases Amyotrophic Lateral Sclerosis, Epilepsy, Psychotic disorders, Schizophrenia, Bipolar disorder

MODULE V: Neurobiology Techniques: Neuronal cell culture, Animal behaviour analysis in Neuroscience, Electrophysiology, Whole Brain Imaging; fluorescence, functional magnetic resonance imaging (fMRI), positron emission tomography (PET), Electrochemical techniques; exocytosis measurements, fast-scan cyclic voltammetry, Calcium imaging, Optogenetics, CLARITY

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2. Neuroscience (7th Edition) by Dale Purves, George J. Augustine, David Fitzpatrick, William C. Hall, Anthony-Samuel LaMantia, Richard D. Mooney, Michael L. Platt, Leonard E. White; 2023
3. Neuroscience: Exploring the brain (Enhanced Edition 4th Edition) by Mark F Bear, Barry W. Connors, Michael A. Paradiso; 2020
4. Basic Neurochemistry Principles of Molecular, Cellular, and Medical Neurobiology. (9th Edition) by Scott Brady, George Siegel; 2024
5. From Neuron to Brain (6th Edition) by John G. Nicholls, A. Robert Martin, David A. Brown, Mathew E. Diamond, David A. Weisblat, Paul A. Fuchs; 2020
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7. Basic Clinical Neuroscience (3rd Edition) by Paul A. young, Paul H. young and Daniel L. Tolbert; 2015
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24-811-0808- PLANT MICROBE INTERACTIONS (4C; 4L+0T+0P)
(Academic Level 400)

Course Description: This advanced course in Plant-Microbe interactions includes the study of Plants as microbial habitat, cellular plant pathogens and the diseases they cause, Defence of plants and stress responses, Invasion of plant tissue-establishment of symbiotic relations; pathogen invasion strategies, Resistance mechanisms against attack by plant pathogens and plant immune system, Methods employed for disease diagnosis, Molecular Basis of Plant Disease Resistance, Plant defence responses against viruses, and Engineering pathogen resistance in crop plants

Course outcomes (CO): After completing the course the student will be able to

Course Outcome		**Cognitive Level**
C.O.1	Analyse the importance of plant-microbe interactions concerning plant diseases	Analyse
C.O.2	Understand and analyse the different plant defence mechanisms and discuss interactions between plants and non-pathogenic/symbiotic bacteria and fungi in agriculture, horticulture and forestry	Understand/Analyse
C.O.3	Apply the conventional and advanced methodology to study the plant-pathogen interaction	Apply
C.O.4	Apply the knowledge on the molecular plant disease resistance mechanisms	Apply
C.O.5	Discuss plant viral diseases and apply that knowledge to generate engineered disease-resistant plants	Apply

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	3							
CO2	2	2	2	1				
CO3	2		2	1				
CO4		2	2	1				
CO5			1				2	1

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Plants as microbial habitat; Introduction to plant-microbe interactions: importance, variety, and two examples (*Fusarium oxysporum* and *Xanthomonas campestris*), symbiotic relations (mycorrhiza, rhizobium), plant diseases cycle, control of plant diseases

MODULE II: Overview of plant defence mechanisms, Infection mechanisms; attachment; enzymes; the role of toxins and other compounds; secondary metabolites of commercial value

MODULE III: Methodology to study plant-microbe interaction- culture techniques, transcriptome profiling, metabolic profiling, proteomics, microscopy, and spectroscopic techniques

MODULE IV: Resistance mechanisms against insect attack; gene-for-gene interactions; The plant immune system- Connecting virulence & resistance; induced resistance

MODULE V: Plant defence responses against viruses, Plant virus transmission; Engineering pathogen resistance in crop plants

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24-811-0809-BIOFUELS AND BIOENERGY (4C; 4L+0T+0P) (Academic Level 400)

Course Description:

This course focuses on bioenergy and the utilization of biomass and biomass waste for energy recovery. The conversion of waste to biofuels, bioenergy and bio-products has been included in the course. The course encompasses thermochemical energy processes (combustion, gasification, pyrolysis), mechanical and chemical processes (oil extraction and trans-esterification), finally biochemical processes (fermentation, anaerobic digestion and bio-electrochemical system). The emphasis is given to Bio-electrochemical systems. The Bio-electrochemical systems used for the conversion of waste to energy such as microbial fuel cells and microbial electrochemical cells has been detailed in this course.

Course Outcomes (CO)

After completing the course the student will be able to:

Course Outcome		**Cognitive Level**
CO 1	Comprehend various technologies used for the synthesis of Biofuel and generation of energy	Understand
CO 2	Illustrate the detailed mechanism and technologies used for the conversion of waste to Bioenergy	Understand
CO 3	Learn the development of microbial fuel cell systems for bio-electricity production	Understand
CO 4	Learn the development of microbial electrochemical systems for bio-hydrogen production	Analyse
CO 5	Practical application of the Bio-electrochemical system	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2	2	1						
CO3		1			1			
CO4			2	1		1		
CO5			2		1		1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module I: Fundamental concepts in understanding Biofuel/Bioenergy production, Renewable feedstock and their production, Biomass pre-processing: drying, size reduction, and densification, Various Biofuels/Bioenergy from biomass

Module II: Biomass conversion to heat and power: thermal gasification of biomass, anaerobic digestion, Biomass conversion to Biofuel: thermos-chemical conversion, syngas fermentation, Biochemical conversion to ethanol: biomass pre-treatment, Different enzymes, enzyme hydrolysis, and their applications in ethanol production. Biodiesel production from oil seeds, waste oils and algae

Module III: Conversion of waste to Biofuels, bio-products and Bioenergy, Types of waste and their distributions, Strategies for waste management, Waste preparation and Pre-treatment for conversion, Technologies for conversion of waste to energy and products.

Module IV: Bioenergy derived from Electro-chemically active biofilms**:** Bioelectricity production, Synthesis of metal Nano-particles, Bio-hydrogen production, Environmental remediation, Microbial fuel cell: Types of Reactors, Methodology**,** Polarization curve, Coulombic efficiency, cyclic voltammetry, Tafel Analysis and Microbial electrolysis cell.

Module V: Environmental impacts of Biofuel production, Energy balance and life-cycle analysis of Biofuel production, Value-added processing of Biofuel residues and co-products;

REFERENCES

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3. Luque, R., & Clark, J. (Eds.). (2010). *Handbook of biofuels production: Processes and technologies*. Elsevier.
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24-811-0810- BIOPROCESSING METHODS AND TECHNIQUES (4C; 4L+0T+0P) (Academic Level 400)

Course Description: This course gives the student an insight into bioprocesses for industrial applications. Differences between bio- and chemical processes, types of bioprocesses, screening for industrially important organisms, strain improvement strategies are all part of this course. In addition, the kinetics of fermentation in batch and continuous mode, the mass transport processes, reactor design, types of reactors, process control and downstream processing of biological are included.

Course Outcomes (CO): After completing the course the student will be able to:

Course outcomes		Cognitive level
C.O. 1	Employ various methods of strain improvement of industrial organisms	Understand
C.O. 2	Employ batch processes, as well as sterilization processes for application	Understand
C.O. 3	Evaluate factors that contribute to the enhancement of cell and product formation during the fermentation process	Understand
C.O. 4	Analyse kinetics of cell and product formation in batch, continuous and fed-batch cultures	Analyse
C.O. 5	Differentiate the rheological changes during the fermentation process	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2	2					
CO2		2	2		1			
CO3			2		1			
CO4			2	1	1			
CO5					2		1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Range of fermentation technology and its chronological development. Basic principle component of fermentation technology. Types of microbial culture. Isolation and screening of industrially useful microorganisms, Primary and secondary screening. Strain improvement in industrial microbiology: mutation and genetic manipulations. Culture Preservation techniques. Screening, detection and assay of fermentation products (physical, chemical and biological assay).

MODULE II: Growth kinetics, primary and secondary metabolites. Feedback inhibition and repression. Types of fermentations: aerobic and anaerobic; submerged and Solid State; Importance of media in fermentation, media formulation and modification. Design of fermentation media Kinetics of growth in batch, continuous, fed- batch fermentation, Storage of cultures for repeated fermentations,

MODULE III: Design of bioprocess vessels: Significance of impeller, Baffles, Sparger, Types of culture/ production vessels: Air-lift, Cyclone column, Packed Tower and their application in production process, Principles of upstream processing. Sterilization: thermal death kinetics, batch & continuous sterilization systems, Sterilization of air, fibrous filters; sterile filtration of biological.

MODULE IV: Introduction to Oxygen requirement in Bioprocess. Energetics of microbial growth in fermenter: Reaction rates, Heat and Mass Transfer, Transport phenomenon in reactors, macroscopic balance of energy and energy flow. Design of a fermenter, instrumentation and process control; Types of fermenter Parts and their functions. Auxiliary instrumentation of bioreactors; Microprocessor controlled fermenters. online measurements;

Monitoring variables such as temperature, aeration, agitation, pressure, pH, foaming; Computers in bioprocess control systems; Economic aspects of bioprocess.

MODULE V: Introduction to Upstream and downstream processing of industrial fermentations: Cell disruptions, Flocculation, Filtrations, Ultra Filtration, Ultra centrifugation, Gel filtration, Chromatographic methods, two phase aqueous separations, Cell and Enzyme immobilization. Fermentation of Antibiotics (Penicillin, Streptomycin), Organic acids (Citric acid, Lactic acid), Enzymes (Penicillin G, Streptokinase), Ethanol and Recombinant Proteins (Insulin).

REFERENCES

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4. Ed. Moo & young 2011,.*Comprehensive Biotechnology*. I, &II, 2nd edition Pergamon Pres.
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SEMESTER IX

SEMESTER IX

24-811-0901- IMMUNOLOGY (4C; 4L+0T+0P) (Academic Level 500)

Course Description: This course is intended to provide a solid grounding in immunology, starting with the basic concepts and proceeding to a deeper understanding of the mechanisms of immune functioning. Special emphasis is given to the 'teamwork' in immune responses. The course also underscores how the system can go wrong, and how it can be corrected or managed using innovative technology. The recently enhanced appreciation of the pre-eminence of the innate immune system, the importance of the intestinal immune system, and the immunomodulatory potential of the gut microbiota are also highlighted. The course also points out the tremendous scope for basic and applied immunological research.

Course Outcomes (CO): After the completion of the course, the student will be able to

Course Outcomes	**Cognitive Level**
C.O.1.Define/recognize the fundamental organization and associations of the immune system.	Understand
C.O.2. Explain/describe/discuss how the immune system functions in a 'teamwork' fashion, and how it is regulated.	Understand
C.O.3. Explain/describe/discuss how the immune system can go wrong, and what types of immuno-pathologies result.	Understand
C.O. 4. Apply appropriate strategies, techniques, and technologies in the management of immune system disorders.	Apply
C.O. 5. Analyze the intricate regulatory mechanisms of the immune system in specific clinical conditions such as hypersensitivities, immunodeficiencies, and autoimmune diseases.	Apply

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	1							
CO2	1							
CO3	1		1					
CO4	1		1	2	1			
CO5	1		1		2			

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: **Introduction to the Immune System**: Historical landmarks, branches, broad divisions of the immune system, antigens vs. immunogens, haptens and carriers, epitopes and paratopes. Hematopoiesis, Theories on immune system functioning; Cells and molecules of the immune system, Inflammation: cellular and molecular events, acute and chronic inflammation, contribution to hypersensitivity and autoimmune reactions; Overview of comparative immunology; Overview of psycho-neuro-endocrine-immunology (PNEI); Overview of the circadian – immune connection; Overview of eco immunology.

MODULE II: **Humoral and Cell-mediated immune responses**: Structure and functions of primary and secondary lymphoid organs; Development, maturation, and functions of T- and B lymphocytes, molecular markers of T- and B- lymphocytes; structure and functions of antibodies, monoclonal vs. polyclonal antibodies, primary and secondary immune responses, clonal selection and clonal expansion, effector cells of the immune system and their specific roles; Generation of receptor diversity (BCR and TCR), subsets of T- and B- cells; Complement: the 3 pathways, regulatory molecules, disorders of the complement system.

MODULE III: **Strategies of immune functioning**: MHC/HLA: its structure, functions, and role in antigen presentation, disorders of antigen processing and presentation, the relative risk associated with specific MHC haplotypes; Lymphocyte trafficking and interaction at the germinal centres, the role of HEV in lymphocyte trafficking; Immune responses against bacteria, fungi, parasites, viruses, and prions; Immune evasion strategies of pathogens.

MODULE IV: **Clinical immunology**: Immunodeficiencies; Hypersensitivity reactions; Autoimmune diseases; Transplantation immunology; Tumour immunology

MODULE V: **Immuno-prophylaxis and Immuno-technology**: Nanotechnology and its applications in immunology; Hybridoma technology and its applications in medicine; Vaccines: their development, and applications in medicine; Immune manipulation of the intestinal immune system, and the gut microbiota Consolidated immunotherapeutic strategies concerning hypersensitivity, autoimmunity, transplantation, immunodeficiencies, and tumour immunology.

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24-811-0902- GENETIC ENGINEERING (4C; 4L+0T+0P) (Academic Level 500)

Course Description: This is an advanced course dealing with the tools and techniques involved in manipulating DNA. The various modules elaborate the different enzymes, the types of vectors used, the expression systems, the heterologous host systems used as well as the various cloning strategies and the processes involved therein. In addition techniques such as

PCR, blotting, site-directed mutagenesis, gene transfer and various screening strategies are also included.

Course Outcomes (**CO**): After the completion of the course, the student will be able to

Course Outcomes	**Cognitive Level**
C.O.1: Elaborate the different enzymes, vectors, as well as cloning strategies	Understand
C.O.2: Apply the different enzymes used in genetic engineering.	Apply
C.O.3: Use different types of vectors for cloning	Apply
C.O. 4: Produce a genomic DNA library and screening for recombinants and construct a probe and do blotting techniques	Analyse
C.O. 5: Employ different types of PCR techniques for gene amplification and clone the amplicon	Analyse

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	1	2	1					
CO2	1		1					
CO3	1		2		1	1		
CO4	1	2				1		
CO5	1	1		1				

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Enzymes in rDNA technology: Restriction–modification systems, Deoxyribose nucleases: exonucleases and endonucleases, Restriction enzymes-type-I, II, and III. S1 Nucleases, DNA Ligases, Alkaline phosphatase, DNA polymerase.

MODULE II: Cloning strategies: Shotgun cloning, amplicon cloning, cDNA cloning and its advantages and disadvantages. Construction of genomic DNA and cDNA libraries: Cloning Vectors -plasmids, lambda phage, SV40, Phagemids; Construction of artificial chromosome vectors-BAC & YAC; Expression systems and their applications.

MODULE III: Recombinant DNA-tailing, cohesive ends: Use of linkers, blunt end methods; In vitro packaging, Host vector systems; Probe construction; recombinant selection and screening; Southern hybridization, Colony hybridization, Plaque hybridization.

MODULE IV: Applications: PCR: RT-PCR, Inverse PCR, Nested PCR, LAMP; Molecular Markers - RAPD, RFLP, DNA fingerprinting, microsatellites and mini-satellites, SNPs, ESTs, Barcoding; Site-directed mutagenesis; Gene transfer in animals and plants: direct gene transfer and molecular chimeras Microinjection, electroporation, biolistic, direct gene transfer using PEG, calcium chloride, calcium phosphate; Vector mediated gene transfer-Agrobacterium mediated transfer.

MODULE V: Heterologous protein expression in prokaryotes and Eukaryotes- Expression in *E. coli*, yeasts and mammalian cells; Advantages and disadvantages of the various expression systems; cloning of genes into vectors; production and subsequent characterization of the recombinant protein. Genome editing strategies: CRISPR-Cas, TALENS, ZFNs, engineered nucleases, mega-nucleases; MAGE and applications.

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24-811-0903 IMMUNOLOGY & GENETIC ENGINEERING LAB (4C; 0L+0T+8P) (Academic Level 500)

Course Outcomes (**CO**): After the completion of the course, the student will be able to

Course Outcomes	**Cognitive Level**
C.O. 1: Evaluating the blood cell indices using a haemocytometer	Analyse
C.O. 2: Define the basic principles of heaemagglutination and immunodiffusion	Remember
C.O. 3: Analyse antibodies or complement proteins attached to blood cells using diagnostic techniques	Analyse
C.O. 4: Describe the basic principles of immune electrophoresis and evaluate and quantify peptides, proteins, antibodies, and hormones using the ELISA technique	Analyse
C.O. 5: Apply knowledge of molecular biology, immunogenetics to detect specific proteins using western blotting techniques	Apply

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	2		1	1				
CO2	2		1	1	1			
CO3	1		1	2				
CO4	1		1	1	1			
CO5	1		2			2		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

LIST OF PRACTICAL

Immunology

1. Differential white cell count
2. Haemagglutination (Direct and Indirect)

3. Immunodiffusion (Ouchterlony, Mancini)
4. Complement fixation test
5. Coombs' test
6. Basic immunoelectrophoresis
7. Rocket immunoelectrophoresis
8. Western blotting
9. ELISA
10. HLA typing (immunological and PCR-based)

Genetic Engineering

1. Isolation of genomic DNA
2. Isolation of plasmid DNA from transformed *E. coli*
3. Restriction digestion and analysis of DNA
4. Isolation of total RNA and cDNA library construction (Demo)
5. Preparation of competent cells and Transformation in *E. coli*
6. Construction of genomic DNA library
7. PCR Techniques
8. Real-time PCR (demonstration)
9. DNA sequencing (demo by industrial visit)

24-811-0904 ONLINE COURSE (2C; 2L+0T+0P) (Academic Level 500)

24-811-0905- NGS AND DATA ANALYSIS (4C; 4L+0T+0P) (Academic Level 500)

Course Description: This course provides a strong understanding of the different Next-generation sequencing platforms, which have become the premier tools in genetic and genomic analysis. The course will also provide a better overview of the different public datasets and different file formats in the NGS platforms. The course provides hands-on experience on the R and Linux platforms, which are the inevitable tools for NGS data processing. The course will also introduce the basics of structural biology and molecular docking. The course layout has adapted to the needs of beginners in the field of life science and allows students with no or little background in bioinformatics to get a first hands-on experience in this fast-evolving topic

Course Outcomes (CO): After completing the course the student will be able to:

Course outcomes		**Cognitive level**
C.O.1	Explain the fundamentals of next-generation sequencing technologies	Understand
C.O.2	Explain the NGS workflow, data files and formats	Understand
C.O.3	Analyse and visualize data using R	Analyse
C.O.4	Effectively analyse and interpret RNA sequencing and genome data	Analyse
C.O.5	Effectively predict and analyse the structure of proteins	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	1							
CO3	1			2				
CO4	1	1	1	2		2		
CO5	1	2						

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Introduction to Next Generation Sequencing (NGS): Principles of NGS technology, Major Applications of NGS, Different NGS Platforms: Illumina, Ion Torrent Semiconductor Sequencing, Pacific Biosciences SMRT, Oxford Nanopore Technologies. Data mining: Database for biological datasets, accessing information from public databases, Sequence storage and retrieval and various file formats

MODULE II: Operating Systems and Concepts: Basic introduction to different Operating systems. Linux: Introduction to Linux, basic commands used for Navigation and Directory controls. File Maintenance Commands, Display Commands and print commands, working with the files, file attributes, pipes, wildcards, working with processes working with basic editors. Basic regular expressions, string search applications using regular expressions. Spreadsheet applications: An introduction to the different spreadsheet applications

MODULE III: Introduction to R: Defining the R project, Obtaining R, Generating R codes, Scripts, Text editors for R, Graphical User Interfaces (GUIs) for R, R Studio, R Packages. R Objects and data structures: Variable classes, Vectors and matrices, data frames and lists, Data sets included in R packages, Summarizing and exploring data, Reading data from external files- tables, fasta files, Storing data to external files, creating basic plots like histograms, scatterplots and bar charts, Creating and storing R workspaces.

MODULE IV: RNA Seq and Genome sequencing: Principles of RNA Sequencing and experimental design, De novo and Resequencing approaches. File format and Quality control: Quality control of datasets obtained from public datasets, Filtering, adapter removal, Mapping, RNA-Seq Data Normalization, Identification of Differentially Expressed Genes, Functional Analysis of identified genes. Genome sequencing: Principles of Genome sequencing and experimental design, Sequencing Strategies for De novo Assembly: Assembly of Contigs, Assessment of Genome Characteristics, Contig Assembly Algorithms; Scaffolding, Assembly Quality Evaluation and Gap Closure. Comparative genomics: Tools and applications

MODULE V: Structural databases: Introduction to structural databases, Protein Data Bank, Molecular Modelling Data Bank, Protein structure prediction- homology modelling, fold recognition, template free modelling. Protein folding problems, Introduction to drug designing and docking methods to generate new structures, Tools for molecular docking.

REFERENCES

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4. Gentleman, R., Carey, V., Huber, W., Irizarry, R., & Dudoit, S. (Eds.). (2006). *Bioinformatics and computational biology solutions using R and Bioconductor*. Springer Science & Business Media.
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8. Pevsner, J. (2015). *Bioinformatics and functional genomics*. John Wiley & Sons.
9. Sarwar, S. M., & Koretsky, R. M. (2016). *UNIX: the textbook*. CRC Press.
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24-811-0906- ENVIRONMENTAL MICROBIOLOGY (4C; 4L+0T+0P)
(Academic Level 500)

Course description: This course gives the student an insight into environmental microbiology including a brief history and development of environmental microbiology; aerobiology, aquatic microbiology, microbial diversity insoil and in extreme environments; culture-dependent and culture-independent approaches for understanding microbial diversity in the environment; microbial interactions; microbes in biodegradation of organic compounds, microbes in waste management including liquid waste and solid waste, bioremediation of environmental pollutants

Course outcomes (CO) : After completing the course, the student will be able to

Course outcomes		**Cognitive level**
C.O.1	Discuss the significant contributions of microbiologists, the emergence of environmental microbiology, biogeochemical roles, and significant applications of microbes in solving environmental pollution problems	Understand
C.O.2	Discuss the diversity of microbes in the air, aquatic environments, and drinking water and apply the same for the conservation of the environment and sustainable utilization of environmental resources	Apply
C.O.3	Discuss the diversity of microbes in soil and in extreme environments for the conservation of the environmentand apply the same for sustainable utilization of environmental microorganisms	Apply
C.O.4	Discuss about indicator organisms, municipal solid and liquid waste management and apply using waste management techniques	Apply
C.O.5	Discuss the bioremediation of environmental and metal pollutants and use microbes for bioremediation or organic and metal pollution	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	2	1	1					
CO3	1							
CO4	2		1	1		2		
CO5	1					1		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Brief history and development of environmental microbiology: History and development of microbial ecologyhighlighting significant contributions of microbiologists and emergence of environmental microbiology, and significant applications of microbes in solving environmental pollution. Microbial biogeochemistry, C, N, S, P, Fe cycles. Role of microorganism in the maintenance of the fertility of soil and self-purification of rivers and aquatic bodies; Environmental Concerns in releasing genetically engineered microorganisms in environment; Microorganisms in biological warfare and bioterrorism. **Culture-dependent and culture-independent approaches** for Understanding microbial diversity in the environment.

MODULE II: Aerobiology- -Microbial contamination of air – Sources of contamination- Microbial indicators of air pollution.Enumeration of bacteria in air, Air sampling devices. Air sanitation. Effect of Air Pollution on Plants and Humans. **Aquatic microbiology:** Diversity of microbes in aquatic environments, Microbiology of drinking water, – Water pollution and water borne pathogens –Bacteriological examination of water – Indicator organisms. Purificationanddisinfection of water. Role of microbes in marine fouling and corrosion. Marine microbes and climate change.

MODULE III: Microbial diversity in soil: Diversity of microbes in terrestrial (agricultural and desert soils) environments, and animal (cattle, termites, pests such as cockroaches and nematodes, and human beings), plants and their role in the ecosystem. **Microbial diversity in extreme environments:** Occurrence, diversity, adaptations and potential applications of oligotrophs, thermophiles, psychrophiles, barophiles, organic solvent and radiation tolerants, metallophiles,acidophiles, alkaliphiles and halophiles.

MODULE IV: Indicator Microorganisms, Total Coliforms, Fecal Coliforms and *Escherichia coli*. Fecal Enterococci. *Clostridium perfringes*. Bacteroides and Bifidobacterium. Heterotrophic Plate Count, Bacteriophages. Municipal Wastewater Treatment, Drinking Water Treatment The Nature of Wastewater, Conventional Wastewater Treatment. Oxidation Pools. Septic Tanks. Wetlands Systems Sludge Processing. Treatmentof Industrial effluents (distillery, textile, pulp and paper).. **Solid waste management:** composting, anaerobic digestion & biomethanation

MODULE V: Microorganisms and Organic Pollutants, The Overall Process of Biodegradation, Contaminant Structure, Toxicity, and Biodegradability. microbial degradation of cellulose, lignocellulose, paper, textiles, leather, rubber, emerging contaminants and xenobiotics. Environmental Factors Affecting Biodegradation, Biodegradation of Organic Pollutants. Bioremediation. Bioremediation of environmental pollutants: Petroleum hydrocarbons **Genetically modified microorganisms and Biotechnology.**

Microorganisms and Metal Pollutants. Metals in the Environment. Metal Solubility, Bioavailability, and Speciation. Metal Effects on the Microbial Cell. Mechanisms of Microbial Metal Resistance and Detoxification, Microbial Metal Transformations, Microbial Approaches in the Remediation of Metal-Contaminated Environments.

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10. A. Singh and O.P. Ward, 2004. Applied Bioremediation and Phytoremediation by Springer,.
11. K-E.L. Eriksson, R.A. Blanchettee and P. Ander, Springer, 1990. Microbial and Enzymatic Degradation ofWood and Wood components,
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13. I.L.Pepper and C.P.Gerba, 2004, Environmental Microbiology-A Laboratory Manual. Elsevier, Academicpress

24-811-0907- MICROBIOME (4C; 4L+0T+0P) (Academic Level 500)

Course description: This course provides an overview of the role of microbiome in human health and disease. It focuses on conceptual frameworks and technologies for understanding how microbiomes, particularly gut microbiomes impact human health and well-being. This course will cover the various microbiomes such the gut, soil, plant, oral, skin etc. The course will also discuss the dysbiosis and rebalancing of the microbiome, The course will also cover various omics techniques used to study the microbiome and microbiome strategies for the treatment of diseases

Course outcomes (CO) After completing the course, the students will be able to:

Course outcomes		**Cognitive level**
C.O.1	Illustrate ecological principles of the human microbiomes, and the importance of conservation of the global microbiomes of peoples from different human populations to development and health	Understand
C.O.2	Discuss the growing importance of considering the human gut microbiome in the treatment and prevention of diseases and illness and to assess the potential of the microbiota (probiotics) and diet (prebiotics) to achieve and maintain health	Apply
C.O.3	Discuss the significance of the microbiome of the environment, soil, water, plant, skin, oral cavity etc and to apply the same for maintaining human health and ecological balance	Apply
C.O.4	Discuss and understand the current technologies in next-generation sequencing and metagenomics in interpreting the role of the human microbiome	Apply
C.O.5	Discuss the application of microbiome for therapeutic purposes	Apply

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	2							
CO2	1	1	1					
CO3	2		1				1	
CO4	1	2						
CO5	1	1					1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Introduction to the human microbiome. Human microbiome at various taxonomic levels, from the domains of bacteria, fungi and viruses down to species and strain-level differences. Other microorganisms of the human microbiome, The mycome and virome in health and disease. Pathobionts and pathogens, Opportunistic infections, Spore-forming opportunists. Dynamics of microbiome from birth to adulthood. The importance of organismal microbiomes for immunity and metabolism.

MODULE II: The gut microbiome, Diet and the human microbiome, Microbial imbalances and perturbations: Dysbiosis and the gut microbiome, Antibiotics and the human microbiome, Drug metabolism by the microbiome, Behaviour and the microbiome (the gut-brain axis), Rebalancing of the microbiome: Probiotics, prebiotics and the human microbiome, Current probiotics– from faecal transplants to yoghurts

MODULE III: The skin microbiome. Environmental Microbiome. (Soil, water). Plant microbiome, Animal microbiome. Oral Microbiome, The Microbiome of the Geno-urinary System Oncobiome. Specialised pathogens and their tricks, Food poisoning, enteropathogenic *E. coli* and *Salmonella* (type III secretion systems II), Yersinia and the black death (type III secretion systems I) STDs and *Neisseria gonorrhoeae* (genomic flexibility)

MODULE IV: Introduction to metagenomics and next generation sequencing. DNA-based analysis of microbial communities, 16S rRNA gene amplicon sequencing and shotgun metagenomics sequencing methods. Functional analysis of the microbiome from DNA sequence functional analysis, meta-transcriptome, metabolome, proteome, and glycome.

MODULE V: Exchange between the human microbiome and the built environment. Comparative microbiomes from other animals. Next-generation therapies for microbial dysfunction and pathology Phage therapy. Microbiome engineering and its promises. Use of animals in microbiome research.

REFERENCES

1. The Gut Microbiome in Health and Disease (2018). Dirk Haller. The Gut Microbiome in Health and Disease. ISBN 978-3-31-990544-0, 978-3-31-990545-7
2. Fundamentals of Microbiome Science: How Microbes Shape Animal Biology. (2018). Angela e Douglas. ISBN. 978140088982
3. The Microbiomes of Humans, Animals, Plants, and the Environment. 2021. Andrés Moya. ISBN: 2662-6128, PRINT ISSN: 2662-611X
4. The Marine Microbiome. 2022. Lucas J. Sta, Mariana Silvia Cretoiu
5. Gut Microbiome-Related Diseases and Therapies. 2021. Maria Gazouli. George Theodoropoulos

24-811-0908 MOLECULAR VIROLOGY *(*4C, 4L+0T+0P) (Academic Level 500)

Course description- The aim of this course is to provide basic knowledge of viruses, viral diseases, and topics important to the control of viral infections including vaccines and antiviral therapy. Replication mechanisms, molecular pathogenesis, host-pathogen interactions, immune evasion strategies, development of antivirals and vaccines, and the relationship between viral evolution and emerging viruses will be taught using representative viruses from different viral families. Rather than covering most of the important microorganisms, select representative model organisms will be taught in detail with the goal that students will be able to apply knowledge and concepts in self-study moving forward in their education and careers. The course also covers currenttrends in emerging viral infections important to public health and biosafety practices in virology laboratories.

Course outcomes (CO) - After completing the course, the students will be able to

Course outcomes		**Cognitive level**
C.O.1	Understand the classification and nomenclature of viruses, nature of viruses and their structure	Understand
C.O.2	Describe molecular details of replication of viruses with different nucleic acid genomes	Analyse
C.O.3	Describe some of the major viral diseases, their pathogenic mechanisms, transmission and clinical symptoms. Describe how specific viruses evade and/or subvert host innate and adaptive immune functions	Analyse
C.O.4	Employ testing viral diseases by various techniques and conduct diagnostic tests for viral diseases and explain how specific antiviral therapies interfere with viral biology to treat infection	Apply
C.O.5	Employ biosafety practices for handling infectious viruses	Apply

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	2							
CO2	2	1						
CO3	2		1	2		1		
CO4	2		2	1	1			
CO5	2		1					

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I- Introduction to virology: History and principles of virology, Virus structure and morphology, Classification, and nomenclature of viruses, ICTV and Baltimore. Routes of entry and transmission, acute and persistent infections, tissue tropism

MODULE II- The viral replication cycle: Replication strategies for DNA and RNA genome viruses, Host-pathogen interactions, viral receptors, attachment and entry of enveloped and non-enveloped viruses, Viral entry pathways-fusion, endocytosis, uncoating, cytoplasmic trafficking, nuclear entry, replication, maturation, and release

MODULE III: Molecular Pathogenesis and Transmission of viral diseases:
(1) dsDNA Viruses: Herpesvirus (Adeno virus, Herpes simplex virus, Pox Virus),
(2) ssDNA Viruses : Parvovirus
(3) dsRNA viruses – reoviruses
(4)+ ssRNA Viruses: Picornavirus (Poliovirus), Coronavirus.
(5) -ssRNA Viruses: Orthomyxovirus (Influenza virus), paramyxoviruses, rhabdoviruses
(6) ssRNA viruses with Reverse Transcriptase – retroviruses.
(7) dsDNA viruses with Reverse Transcriptase – hepadnaviruses
Emerging and re-emerging viruses that infect humans and animals: Filovirus (Ebola virus), Nipah, SARS-CoV2, Togavirus (Chikungunya virus), Flavivirus (Dengue Virus), *etc.*
Viral oncogenesis. Immune response to viral infection, viral immune escape mechanism.

MODULE IV: Detection and prevention: Eradication of viral diseases. Diagnosis of viral diseases: microscopy, serological diagnosis-ELISA. PCR immunocytochemistry, immunohistochemistry, haemagglutination, Western blot. Cultivation and enumeration of animal viruses. Plaque assay, LD 50 and TCID 50. **Antiviral agents and vaccines**: Interferons - mode of action and importance in therapy. Antivirals and antiretrovirals-mechanism of action, HAART therapy. Viral vaccine- Different types and their production — Killed and attenuated vaccines, recombinant viral vaccine, subunit vaccines. Virus as vectors for vaccination. Adjuvants.Vaccine delivery. Anti-sense RNA, siRNA, ribozymes

MODULE V: Biosafety in virology laboratory: Classification of viruses into hazard groups. Bio-safety level and biosafety cabinets. Disinfection, decontamination, solid and liquid waste disposal in virology laboratory

REFERENCES

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8. Brian WJ Mahy and Hillar O Kangro. Virology Methods Manual Elsevier
9. John R. Stephenson, Alan Warnes. Diagnostic Virology Protocols: Methods in Molecular Medicine. HumanaPress. Springer Link
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15. Brenda S. P. Ang, Tchoyoson C. C. Lim, Linfa Wang. Nipah Virus Infection Journal of Clinical Microbiology,Volume 56 Issue 6 e01875-17, June 2018, Chapter 11 - Nipah Virus: A Virus with Multiple Pathways of Emergence. Pages 293-315 A Review Article:
16. Editors: Saxena, Shailendra K. (Ed.)2019 Coronavirus Disease 2019 (COVID-19) ,Epidemiology, Pathogenesis, Diagnosis, and Therapeutics
17. Marco Cascella; Michael Rajnik; Arturo Cuomo; Scott C. Dulebohn; Raffaela Di Napoli.2019Features, Evaluation and Treatment Coronavirus (COVID-19) - https://www.ncbi.nlm.nih.gov/books/NBK554776/

24-811-0909- ENVIRONMENTAL BIOTECHNOLOGY (4C; 4L+0T+0P)
(Academic Level 500)

Course Description: Environmental Biotechnology explores the application of biological principles and processes to address environmental challenges. This interdisciplinary field integrates concepts from microbiology, biochemistry, engineering, and environmental science to develop sustainable solutions for pollution control, waste management, and resource recovery. Students will gain an understanding of the role of microorganisms, plants, and biotechnological techniques in mitigating environmental pollution, enhancing ecosystem resilience, and promoting environmental sustainability.

Course outcomes (CO): After completing the course. the student will be able to:

Course outcomes		**Cognitive level**
C.O.1	Discuss the fundamental principles in the fields of Environmental biotechnology that uses biology to tackle environmental issues sustainably,	Understand
C.O.2	Discuss the vital role microorganisms play in environmental processes and develop skills to apply microbial-based solutions to address environmental challenges effectively.	Understand
C.O.3	Appreciate practical knowledge and skills in selecting, designing, and implementing bioremediation strategies for various environmental contaminants, contributing to the development of sustainable solutions for pollution remediation and environmental protection	Understand
C.O.4	Discuss about waste management principles and sustainability and device strategies for bioconversion of waste to value-added products, and circular economy	Apply
C.O.5	Explain the importance of environmental monitoring, techniques for assessing air, water, and soil quality,	Understand

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	1							
CO2	2	2						
CO3	2		2	2		1		
CO4	1		2	2	2			
CO5	1		1					

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Introduction to Environmental Biotechnology- Overview of environmental biotechnology, Importance and scope of environmental biotechnology in addressing environmental issues, Historical development and milestones in environmental biotechnology, Principles of sustainable development and their relevance to environmental biotechnology

MODULE II: Environmental Microbiology-Microbial ecology and diversity in natural environments, Microbial metabolism and interactions relevant to environmental processes, Biodegradation and bioremediation processes, Role of microorganisms in wastewater treatment, soil remediation, and pollution control

MODULE III: Bioremediation Techniques-Introduction to bioremediation techniques and strategies, Physicochemical methods vs. bioremediation approaches, Microbial degradation of organic pollutants, Phytoremediation and its applications in environmental clean-up, Case studies and real-world applications of bioremediation technologies

MODULE IV: Waste Management and Resource Recovery- Principles of waste management and environmental sustainability, Anaerobic digestion for organic waste treatment and energy recovery, Composting techniques and applications in organic waste management, Bioconversion of waste to value-added products (e.g., biofuels, bioplastics), Circular economy concepts and their integration into waste management strategies

MODULE V: Environmental Monitoring and Assessment- Importance of environmental monitoring and assessment, Techniques for monitoring air, water, and soil quality, Biomonitoring approaches using indicator species and bioindicators, Risk assessment methodologies for environmental contaminants**.** Remote sensing and GIS applications in environmental monitoring and management

REFERENCES

1. Environmental Biotechnology: Principles and Applications" by Bruce Rittmann and Perry McCarty (2019)
2. "Biotechnology for Environmental Management and Resource Recovery" by G. Sridevi and T. Satyanarayana (2017)
3. "Environmental Biotechnology: A Biosystems Approach" by Daniel Vallero and Chris Callahan (2010)
4. "Principles of Environmental Biotechnology" by T. K. Bhattacharya and S. A. Dhillon (2015)
5. "Bioremediation: Principles and Applications" by Ronald L. Crawford and Don L. Crawford (2017)
6. "Handbook of Environmental Engineering: Environmental Biotechnology and Biodegradation" edited by Myer Kutz (2019)
7. "Environmental Biotechnology: Basic Concepts and Applications" by Indu Shekhar Thakur (2016)
8. "Biotechnology for Environmental Protection in the Pulp and Paper Industry" edited by Pratima Bajpai (2018)

24-811-0910- PLANT BIOTECHNOLOGY (4C, 4L+0T+0P) (Academic Level 500)

Course Description: This course integrates plant physiology with plant tissue culture techniques, covering gene identification, transgenic plant creation, and advanced methods like Map-based cloning. It includes practical training in tissue culture and genetic transformation, alongside discussions on secondary metabolite production, genetic diversity preservation, and plant-based carbon sequestration for climate change mitigation.

Course outcomes (CO)
After completing the course the student will be able to:

Course outcomes		**Cognitive level**
C.O.1	Discuss the fundamental principles and techniques in the fields of plant physiology and practical skills and theoretical knowledge to create and manipulate plant tissues for various applications.	Understand
C.O.2	Device strategies to provides a solid introduction to plant genome analysis and gene identification techniques, essential for understanding plant genetics and improving crop traits	Analyse
C.O.3	Appreciate the latest techniques that provides a comprehensive overview of gene transfer methods used to produce transgenic plants with desired traits.	Understand
C.O.4	Formulate strategies of genetic engineering that offers powerful tools for enhancing agricultural productivity, improving crop quality, and addressing global food security challenges	Analyse
C.O.5	Explain the enhancing secondary metabolite production, preserving genetic diversity, and utilizing plant-based carbon sequestration for climate change mitigation.	Understand

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	3		2					
CO2	2		2	1				
CO3	2	1	2					
CO4	2	2		1				
CO5	2					2	1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: **Overview of uniqueness of plants:** General Introduction on physiological processes of higher plants, water relations of plants-, Includes transpiration (water loss), guttation (water exudation), and plasmolysis (cellular water loss). Photosynthesis: Process converting light energy into chemical energy (glucose) in chloroplasts. Involves light reactions (ATP/NADPH production) and Calvin cycle (CO2 fixation).Different pathways (C3, C4, CAM) optimize photosynthesis under varying conditions.

Plant Tissue Culture: Basic concepts: Totipotency: Cells' ability to regenerate into whole plants. Organogenesis: Formation of organs from cultured tissues.Somatic Embryogenesis: Embryo formation from somatic cells. Techniques: Techniques:
Callus, cell suspension, anther, ovule, root, shoot tip, and meristem cultures.
Protoplast culture for genetic manipulation. Micropropagation for rapid, mass plant production. Medicinal and ornamental plant conservation and propagation. Somaclonal variations and their implications. Artificial seed development for plant propagation and storage.

MODULE II: **Plant Genome analysis**; Gene Isolation –Gene Tagging: Identifying genes by linking them to visible markers. Insertional Mutagenesis: Introducing foreign DNA to disrupt gene function and create mutants. Molecular Markers:DNA sequences aiding genetic mapping and trait analysis (e.g.,RFLP, RAPD, AFLP SSRs, ESTsSNPs), Mapping Populations, Marker-Assisted Selection (MAS) / Genomic Selection: **Identification of Candidate Genes**: Genetic Information (Positional Cloning) Biochemical and Expression Analysis: Transformation: Mutant Populations and Knockout Systems: Heterologous Expression Systems: Protein Analysis

MODULE III: The Gene transfer Techniques for the production of Transgenic: Indirect Gene transfer Methods: **Structural Features of Ti Plasmid, Mechanism of Gene Transfer to Plants, Molecular Events in Agrobacterium-Mediated Gene Transfer.** Direct gene transfer methods: **Particle Bombardment (Biolistics), Silicon Carbide Fiber-Mediated Transformation, Electroporation, Microinjection, PEG-Mediated Transformation.** Reporter Genes: Genes encoding proteins with easily detectable phenotypes (e.g., β-glucuronidase, green fluorescent protein) Scorable and Selectable Markers: (e.g., antibiotic resistance agents (e.g., herbicides, antibiotics)for the identification and propagation of transgenic cells or plants.

MODULE IV: Applications of Genetic Engineering in Agriculture: **Golden Rice:** Engineered to produce beta-carotene, addressing vitamin A deficiency. **Bt Crops:** (Cotton, Brinjal, Mustard) Provide pest resistance via Bt toxin expression**. Crop Resistance Traits: Herbicide Resistance:** Enables weed control with specific herbicides. **Pathogen Resistance:** Protection against viruses, bacteria, and fungi. **Oil Modification:** Alters oil composition for improved nutrition or industrial use. **Current Status of Transgenic Plants:** Commercial adoption in India and globally, notably Bt cotton. **Abiotic Stress Resistance:** Developing crops resilient to drought, salinity, etc.

RNAi Applications: Antisense RNA: Targets specific mRNA for gene regulation. **Genome Editing Tools:** ZFNs, TALENs, CRISPR-Cas9 for precise modifications, **Control of Pollination:** Ensure genetic purity via male sterility or GURT, Production of Biopharmaceuticals: Use plants for antibody, vaccine production, with strict regulation.

MODULE V: Plant Metabolic Engineering; Secondary metabolite production: plant products of industrial importance, cell suspension culture, growth kinetics and cell viability, nutrient media optimization; Scale-up studies: elicitors and precursors; Modes of culture: batch, fed-batch and continuous cultures, cell immobilization, biotransformation; Principles, design and operation of bioreactors: instrumentation, agitation, aeration system, temperature, foam control; Downstream processing: extraction, cell disruption, chromatography and purification of metabolites.

Germplasm Conservation: Importance of genetic diversity in agriculture and biodiversity conservation, Overview of germplasm conservation techniques. Role of germplasm conservation in climate change resilience.

Carbon Sequestration in Plants: Strategies for enhancing carbon fixation, Biomass production and carbon storage in plant tissues, Soil carbon sequestration through plant-microbe interactions, Reforestation, afforestation, and carbon farming practices.

REFERENCES

1. Plant Biotechnology: Current and Future Applications of Genetically Modified Crops" by Nigel Halford and Angela Karp (2019).

2. "Plant Biotechnology and Agriculture: Prospects for the 21st Century" edited by Arie Altman (2021).
3. "Plant Biotechnology: Principles and Applications" by Satbir Singh Gosal and G. S. Chauhan (2020).
4. "Plant Biotechnology: The Genetic Manipulation of Plants" by Adrian Slater, Nigel W. Scott, and Mark R. Fowler (2010).
5. "Plant Biotechnology: Recent Advancements and Developments" edited by Sunil Kumar and Surajit Das (2021).
6. Chilton, M. D., & Tu, J. (2020). Plant Metabolic Engineering. Springer.
7. Tanksley, S. D., & McCouch, S. R. (Eds.). (2021). Plant Genetic Resources and Climate Change. John Wiley & Sons.
8. "Principles of Plant Biotechnology: An Introduction to Genetic Engineering in Plants" by H. S. Chawla (2011).
9. "Plant Biotechnology and Genetics: Principles, Techniques, and Applications" by C. Neal Stewart Jr. (2008).
10. "Introduction to Plant Biotechnology" by H. S. Chawla (2013).
11. "Plant Biotechnology: The Genetic Manipulation of Plants" by Adrian Slater, Nigel W. Scott, and Mark R. Fowler (2008).
12. "Plant Biotechnology: Techniques and Applications" by C. Neal Stewart Jr. (2010).

24-811-0911- STEM CELL AND REGENERATIVE MEDICINE (4C; 4L+0T+0P) (Academic Level 500)

Course description: Stem cell research and regenerative medicine are one of the fastest-growing areas of biomedical research worldwide. Stem cells are specialized cells, which are undifferentiated and capable of self-renewal and have the potential to develop into differentiated cell types. Stem cells act as organisms reserve cells that replace specialized cells that are damaged or lost during the development. During this course, we explore several aspects of stem cell biology like the microenvironments or the niches that are required to maintain stem cells, asymmetric cell division, the genes required for stem cell fate, and the use of stem cells for medical/therapeutic applications. In addition, students will also get an insight into stem cell transplantation and tissue engineering in regenerative medicine and the ethical issues involved in this field of research.

Course Outcomes (CO): After completing the course the student will be able to:

Course outcomes		**Cognitive level**
C.O.1	Describe different types of stem cells and their specific characteristics and how they differ from fully differentiated cells.	Understand
C.O.2	Analyse the role of various intrinsic and extrinsic factors important for stem cell renewal and differentiation.	Analyse
C.O.3	Analyse the validity of applications of stem cells for regenerative medicine and the possible problems that need to be overcome.	Analyse
C.O.4	Apply techniques based on the use of Embryonic/Fetal, Induced pluripotent and Adult stem cells for regenerative medicine applications to human diseases.	Apply
C.O.5	Analyse the ethical issues associated with Embryonic/Fetal, Induced pluripotent, Adult stem cells and stem cell therapy with a global bioethics perspective and identify gaps in knowledge and retrieve knowledge independently to be able to present a scientifically sound solution.	Analyse& Apply

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	2							
CO2	2	2	2					
CO3	2	1	1					
CO4	2		1	1				
CO5	1					1	1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Origin of stem cells: Origin of stem cells in organogenesis, Properties of Stem cells, Cell fate determination, Cell potency, Embryonic stem cells, Adult/Tissue-specific stem cells, Induced pluripotent stem cells (iPSCs), Cord blood stem cells and amniotic fluid stem cells, Developmental plasticity, Dedifferentiation, Trans-differentiation, Somatic Cells by Nuclear Transfer

MODULE II: Tissue-specific/Adult stem cells: Hematopoietic Stem Cells, Mesenchymal Stem Cells, Neural Stem Cells, Epithelial Stem Cells, Skin Stem Cells, Other tissue-specific stem cells, Cancer stem cells, Adult stem cells in tissue homoeostasis.

MODULE III: Regulation of Stem Cell Fate and Function: Stem cell niche, Morphogens and growth factors, Control of gene expression, Epigenetic regulation, Positional identity and polarity in regeneration, Cellular differentiation and environmental insults/Stress, Morphallaxis, Epimorphosis

MODULE IV: Tissue Engineering and Regenerative Medicine: Three-dimensional cell culture, Organ culture, Organotypic culture, Animal models of stem cell research, Preclinical study design, engineered scaffolds and matrices, Bioprinting of organs and tissues, Artificial skin substitute, Assessing potential stem cell risks and complications, Stem cell therapeutic efficacy and stability, Tumorigenicity

MODULE V: Stem cells from the laboratory to the clinic: Modes of cell and tissue delivery, Biobanking of stem cells, *In vivo* regeneration of tissues by cell transplantation, Immuno-isolation techniques, Regulatory perspectives, good laboratory/manufacturing practice (GLP/GMP), Ethical considerations in regenerative medicine, Autologous stem cell therapy, Xenograft and Allograft.

REFERENCES

1. Principles of regenerative medicine (3rd Edition) by Robert Lanza, Tony Mikos, Robert Nerem; Elsevier Academic Press; 2019
2. Handbook of Stem Cells, Two-Volume Set: Volume 1-Embryonic Stem Cells; Volume 2-Adult & Fetal Stem Cells (v. 1). Academic Press; 2013
3. Stem Cells: scientific facts and fiction by Christine Mummery; Ian Sir Wilmut; AnjaVan, De, Stolpe; Bernard Roelen; Elsevier Academic Press; 2011
4. Essentials of Stem Cell Biology. (3rd Edition) By Robert Lanza and Anthony Atala, Elsevier Academic Press; 2013
5. Imaging and Tracking Stem Cells: Methods and Protocols (1st Edition) by Kursad Turksen, Springer Science; 2013
6. Stem Cells & Regenerative Medicine (1st Edition), KrishnaraoAppasani and Raghu K. Appasani; Springer Science, 2011
7. Human Stem Cell Technology and Biology: A Research Guide and Laboratory Manual (1st Edition) by Gary S. Stein, Maria Borowski, Mai X. Luong, Meng-Jiao Shi, Kelly P. Smith, Priscilla Vazquez, Wiley-Blackwell; 2011
8. Stem Cells in Regenerative Medicine: Science, Regulation and Business Strategies; (1st Edition) Alain A. Vertes, NasibQureshi, Arnold I. Caplan, Lee E. Babiss; Wiley-Blackwell; 2015
9. Purifying and Culturing Neural Cells: A Laboratory Manual by Ben A. Barres, and Beth Stevens, 2014
10. Handbook of Stem Cells, Two-Volume Set: Volume 1-Embryonic Stem Cells; Volume 2-Adult & Fetal Stem Cells (v. 1). Academic Press; 2013

24-811-0912- BIOPHARMACEUTICALS (4C; 4L+0T+0P) (Academic Level 500)

Course Description: This course introduces the basic principles of drug action and the principles of pharmacokinetics and pharmacodynamics. Techniques for drug development: Drug design, targeting & delivery; Drug discovery and development: Lead development, Preclinical and clinical studies, Pharmaceuticals derived from plants, microorganisms, fungi and marine organisms; Production of recombinant products and Good manufacturing practices (GMP) are the other topics covered.

Course Outcomes (CO): After completing the course the student will be able to:

Course outcomes		**Cognitive level**
C.O.1	Discuss the basic principles of drug action and the principles of pharmacodynamics and pharmacokinetics.	Understand
C.O.2	Explain the application of various techniques for drug development: Drug design, targeting & delivery	Understand
C.O.3	Devise strategies for drug discovery and development and to evaluate drugs derived from different sources.	Apply

C.O.4	Describe the production of recombinant biopharmaceutical products such as hormones, thrombolytic agents, antiviral agents and recombinant vaccines.	Understand
C.O.5	Explain Good manufacturing practices (GMP) and design standard operating procedures (SOPs) for the production of biopharmaceuticals.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2	2	3	3					
CO3	2							
CO4	2					2		
CO5	1					2	1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: **Basic principles of drug action**: Drug administration: drug dose, basis of dose-response curves and its significance, therapeutic index, therapeutic window, dosage forms, routes of administration; Pharmacokinetics: absorption, distribution, metabolism and elimination of drugs; Pharmacodynamics: types and mechanism of drug action, receptor-mediated drug action, stimulation of second messenger system, drug-receptor interactions, agonists, partial agonists, reversible and irreversible antagonist; Pharmacogenetics.

MODULE II: **Techniques for drug development**: Drug design: ligand and receptor-based, Techniques for measuring receptor-drug binding and its uses in new drug development, Techniques used in assay of drugs, quantification of drugs in the body, Targeted drug delivery, Application of nanomaterials in targeted drug delivery, molecular medicine.

MODULE III: **Pharmacognosy:** Importance of natural drug substances, Drugs derived from natural sources such as plants, bacteria, fungi, marine organisms: antibiotics, antivirals and anticancer compounds. **Phases of Drug Development**: drug discovery, preclinical studies; Clinical studies; review by the regulatory authority, drug approval process and post-market drug safety monitoring.

MODULE IV: **Production of recombinant products**: Insulin, human growth hormone, erythropoietin, interferon, recombinant vaccines, Food vaccines, Pharming, Monoclonal antibody-based therapeutic agents.

MODULE V: **Quality and regulatory guidelines for biopharmaceutical production:** Good manufacturing practices (GMP) for the production of recombinant biopharmaceutical products and the establishment of standard operating procedures (SOPs) for a production process, certification of pharmaceutical products

REFERENCES

1. Calbreath, D. F., and Ciulla, A. P. (1992). Clinical chemistry: a fundamental textbook. WB Saunders Company.

2. Walsh, G. (2003). Biopharmaceuticals: biochemistry and biotechnology. John Wiley & Sons.
3. Walsh, G. (2007). Pharmaceutical Biotechnology: Concepts and applications. John Wiley & Sons.
4. Thompson, A. (1991). Bioactive compounds from Marine organisms. Aspect Publications Ltd.
5. Satoskar, R. S., Rege, N., & Bhandarkar, S. D. (2015). Pharmacology and Pharmacotherapeutics-E- Book. Elsevier Health Sciences.
6. Katzung, B. G., Masters, S. B., & Trevor, A. J. (2004). Basic & clinical pharmacology.
7. Purohit, S. S., Kakrani, H. N., & Saluja, A. K. (2003). Pharmaceutical biotechnology. Agrobios (India).

24-811-0913- GENE SILENCING AND GENOME EDITING (4C; 4L+0T+0P) (Academic Level 500)

Course Description: The Gene Silencing and Genome Editing course explores the principles, techniques, and applications of RNA interference (RNAi) and genome editing technologies. This course provides students with a comprehensive understanding of the molecular mechanisms underlying RNAi and genome editing, as well as practical skills in designing and implementing experiments utilizing these techniques. Ethical considerations and current advancements in the field are also discussed.

Course Outcomes (CO)
After completing the course the student will be able to:

Course outcomes		**Cognitive level**
C.O.1	Understand the molecular mechanisms of RNA interference.	Understand
C.O.2	Explore the principles and applications of genome editing technologies.	Understand
C.O.3	Develop skills in designing and executing RNAi and genome editing experiments using computational approaches	Analyse
C.O.4	Analyse the ethical implications of RNAi and genome editing.	Analyse
C.O.5	Analyse case studies to comprehend real-world applications and challenges of RNAi and genome editing.	Analyse

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**
CO1	2							
CO2	1	2						
CO3	2			1				
CO4	1							
CO5	2			2		2	2	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

MODULE I: Introduction to RNA Interference (RNAi)- Definition and historical context; Mechanisms of RNAi: Small interfering RNA (siRNA) and microRNA (miRNA); Applications in gene regulation, functional genomics, and therapeutics. **RNAi Techniques**- Design and synthesis of siRNA and miRNA; Delivery methods for RNAi molecules; Assays for evaluating RNAi efficiency and specificity

MODULE II: Genome Editing Technologies- Overview of genome editing tools: CRISPR-Cas9, TALENs, ZFNs, etc.; Molecular mechanisms of genome editing; Applications in gene knockout, knock-in, and modulation

MODULE III: **CRISPR-Cas9 Technology**- CRISPR components: Guide RNA (gRNA), Cas9 protein; Designing gRNA for target specificity; Applications in genome editing and gene regulation. **Practical Applications of RNAi and Genome Editing**- Gene silencing in model organisms and cell lines; Genome editing for disease modelling and therapeutic development; RNAi and genome editing in agriculture and biotechnology

MODULE IV: Ethical Considerations in RNAi and Genome Editing- Ethical guidelines and regulatory frameworks; Germline editing vs. somatic cell editing; Case studies: Ethical dilemmas in RNAi and genome editing research and applications

MODULE V: Current Trends and Future Directions-Advances in RNAi and genome editing technologies; Emerging applications in medicine, agriculture, and biotechnology; Challenges and opportunities in the field. **Case Studies and Discussion**- Analysing landmark studies in RNAi and genome editing B. Debating ethical issues and societal implications

REFERENCES

1. "RNA Interference: Methods for Plants and Animals" (2008) edited by T. Doran and C. Helliwell, eISBN : 978-1-78064-365-6
2. Genome Editing-Current Technology Advances and Applications for Crop Improvement (2022) edited by: Shabir Hussain Wani and Goetz Hensel. Springer
3. "CRISPR-Cas: A Laboratory Manual"(2009) edited by Jennifer A. Doudna and Prashant Mali. CSH Press
4. "RNA Interference: Challenges and Therapeutic Opportunities" (2015) edited by Mouldy Sioud, Springer
5. "Ethics of Genome Editing" (2021) European Group on Ethics in Science and New Technologies

SEMESTER X

SEMESTER X

24-811-1001 MAJOR PROJECT (20C; 0L+0T+40P) (Academic Level 600)

24-811-1002 ONLINE COURSE (2C; 2L+0T+0P) (Academic Level 500)**
(if taken in IX for 4C then No need to take here)

Cochin University of Science and Technology

Department of Mathematics

Five Year Integrated MSc Major in Mathematics

Syllabus approved by the

Board of Studies of Physical and Mathematical Sciences

(2024 admission onwards)

Integrated MSc Mathematics Scheme (2024 Admission onwards)

Semester	Details of courses offered in each semester						
	Major **4 credits**	**Minor** **4 credits**	**MDC** **3 credits**	**AEC** **3 credits**	**SEC** **3 credits**	**VAC** **3 credits**	**Total credits**
I	1	2	1	2*			21
II	1	2	1	2*			21
III	1	2	1			2*	21
IV	4				1	1*	22
V	5				1		23
VI	5**				1		23
		Internship***					2
Total credits/courses	68 (17) DSC 60 (15) DSE 8 (2-3)	24 (6)	9 (3)	12 (4)	9 (3)	9 (3)	133

*Courses offered by the Center for Integrated Studies, CUSAT

** One course with 4 credits, maybe replaced with one/two online courses to acquire 4 credits

***Not counted as a course

Exit with BSc in Mathematics (Total credits = 133)

VII	5 Courses + online course / internship (2 credits)						22
VIII	2 Courses + Online / internship (2 credits) + Project (12 credits) Or 4 Major Courses + Mini project (4 credits) + Online course / internship (2 credits)						22
Total credits/courses	Hon. (Research): 112 (26 + Project) Hon. : 112 (28 + Mini Project)	24 (6)	9 (3)	12 (4)	9 (3)	9 (3)	177
Exit with BSc (Honours with Research) in Mathematics (Total credits = 177) Exit with BSc (Honours) in Mathematics (Total credits = 177)							
IX	5 Courses + online (2 credit**)						20-24
X	5* courses + online (2 credit**)						20-24
Total credits	156	24 (6)	9 (3)	12 (4)	9 (3)	9 (3)	221
* A project of 4 credits or 8 credits may be done to replace elective course/s of equivalent credit in the X semester ** Instead of taking two online courses worth 2 credits each, a student can opt for one online course worth 4 credits in the ninth/tenth semester. In such cases, the credits earned in that semester will be 24, and in the other semester, they will be 20. Exit with MSc in Mathematics (Total credits = 221)							

MDC: Multi-Disciplinary Courses
AEC: Ability Enhancement Courses
SEC: Skill enhancement Courses
VAC: Value Added Courses

Details of Courses Offered from Department of Mathematics

for students doing 5-year Integrated MSc

DSC – Department Specific Core, DSE – Department Specific Elective

MDC – Multidisciplinary Course, SEC – Skill Enhancement Course

SEMESTER: 1

Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-0101	Calculus 1	100	DSE (For everyone)	4	4-0-0	50	50	100
24-809-0102	Basic Analysis 1	100	DSC (Only for Major in Mathematics)	4	3-0-2	50	50	100
24-809-0103	Mathematical Methods 1	100	DSE (Offered as Minor / MDC alone)	3	3-0-0	50	50	100

SEMESTER: 2

Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-0201	Calculus 2	100	DSC (Major/Minor)	4	4-0-0	50	50	100
24-809-0202	Basic Analysis 2	100	DSC (Major)	4	3-0-2	50	50	100
24-809-0203	Mathematical Methods 2	100	DSE (Offered as Minor / MDC alone)	3	3-0-0	50	50	100

SEMESTER: 3

Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-0301	Calculus 3	200	DSC (Major/Minor)	4	4-0-0	50	50	100
24-809-0302	Matrix Theory 1	200	DSC (Major)	4	3-0-2	50	50	100
24-809-0303	Matrix Theory and Graph Theory	200	MDC	3	3-0-0	50	50	100

SEMESTER: 4								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-0401	Basic Group Theory	200	DSC	4	3-0-2	50	50	100
24-809-0402	Matrix Theory II	200	DSC	4	3-0-2	50	50	100
24-809-0403	Elementary Complex Analysis	200	DSC	4	3-0-2	50	50	100
24-809-0404	Basics in Python Programming	200	DSC	4	3-0-2	50	50	100
24-809-0405	Skill Enhancement Course	200	SEC	3	3-0-0	50	50	100

SEMESTER: 5								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-0501	Real Analysis I	300	DSC	4	3-0-2	50	50	100
24-809-0502	Complex Analysis	300	DSC	4	3-0-2	50	50	100
24-809-0503	Group Theory	300	DSC	4	3-0-2	50	50	100
24-809-0504	Linear Algebra and Geometry	300	DSC	4	3-0-2	50	50	100
24-809-0505	Skill Enhancement Course	300	SEC	3	3-0-0	50	50	100
24-809-050x	Elective I	300	DSE	4	3-0-2	50	50	100

SEMESTER: 6								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-0601	Real Analysis II	300	DSC	4	3-0-2	50	50	100
24-809-0602	Ring Theory	300	DSC	4	3-0-2	50	50	100
24-809-0603	Ordinary Differential Equations	300	DSC	4	3-0-2	50	50	100
24-809-060x	Elective I	300	DSE	4	3-0-2	50	50	100
24-809-060x	Elective II	300	DSE	4	3-0-2	50	50	100
	Skill Enhancement Course	300	SEC	3	3-0-0	50	50	100
Internship (Not counted as a course)				2				

LIST OF ELECTIVE COURSES OFFERED IN V AND VI SEMESTERS:-

24-809-0505 / 24-809-0605: Discrete Mathematics

24-809-0506 / 24-809-0606: Linear Programming

24-809-0507 / 24-809-0607: Elements of Applied Mathematics

24-809-0508 / 24-809-0608: Introduction to Optimization Techniques

24-809-0509 / 24-809-0609: Metric Topology

24-809-0510 / 24-809-0610: Fuzzy Mathematics

24-809-0511 / 24-809-0611: Introduction to Optimization in Machine Learning

24-809-0512 / 24-809-0612: Elementary Number Theory

A student can exit, if he/she prefers, at this stage with BSc in Mathematics degree with a total credit of 133

SEMESTER: 7								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-0701	Linear Algebra	400	DSC	4	3-0-2	50	50	100
24-809-0702	Measure and Integration	400	DSC	4	3-0-2	50	50	100
24-809-0703	Groups and Rings	400	DSC	4	3-0-2	50	50	100
24-809-0704	Topology I	400	DSC	4	3-0-2	50	50	100
24-809-070x	Elective I	400	DSE	4	3-0-2	50	50	100
	Online Course / Internship			2		0	100	100

SEMESTER: 8								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-0801	Field Theory	400	DSC	4	3-0-2	50	50	100
24-809-0802	Functional Analysis	400	DSC	4	3-0-2	50	50	100
24-809-0803	Complex Analysis	400	DSC / DSE	4	3-0-2	50	50	100
24-809-0804	Functions of Several Variables and Geometry	400	DSC	4	3-0-2	50	50	100
24-809-0805	Minor Project	400	DSC	4			100	100
	Online Course / Internship			2		0	100	100

Students who wish to exit with BSc Honors can opt out elective to do a minor project. Students who wish to exit with a BSc Honors with research must do a research project of 12 credits, for additional credits, or can opt out a maximum of 2 core papers offered in 8th semester. The eligibility to opt for research project and the papers that can be omitted shall be decided by the student in consultation with the project supervisor and with the approval of the department council.

SEMESTER 9								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-0901	Operator Theory	500	DSC	4	3-0-2	50	50	100
24-809-0902	Ordinary Differential Equations and Integral Equations	500	DSC	4	3-0-2	50	50	100
24-809-0903	Elective I	500	DSE	4	3-0-2	50	50	100
24-809-09xx	Elective II	500	DSE	4	3-0-2	50	50	100
XXX 109xx	Elective III	500	DSE	4	3-0-2	50	50	100
	Online Course*			2/4		0	100	100

SEMESTER 10								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-809-1001	Partial Differential Equations and Variational Problems	500	DSC	4	3-0-2	50	50	100
24-809-1002	Probability Theory	500	DSC	4	3-0-2	50	50	100
24-809-10xx	Elective I	500	DSE	4	3-0-2	50	50	100
24-809-10xx	Elective II	500	DSE	4	3-0-2	50	50	100
24-809-10xx	Elective III	500	DSE	4	3-0-2	50	50	100
	Online Course*			2/4		0	100	100

*A student can do either two online courses of two credits each or one online course of 4 credits in either semester 9 or 10.

Project (6 months – 4 credits / 1 year – 8 credits) can be taken instead of elective courses in semester 9 / 10

LIST OF ELECTIVE COURSES OFFERED IN VARIOUS SEMESTERS:-

24-809-0705 : Real Analysis I
24-809-0905 : Topics in Applied Mathematics (Inter-departmental elective)
24-809-0906/ 24-809-1006 : Advanced Linear Algebra
24-809-0907/ 24-809-1007 : Discrete Framelets
24-809-0908/ 24-809-1008 : Harmonic Analysis
24-809-0909/ 24-809-1009 : Integral Transforms
24-809-0910/ 24-809-1010 : Functions Of Several Variables
24-809-0911/ 24-809-1011 : Advanced Spectral Theory
24-809-0912/ 24-809-1012 : Banach Algebras And Spectral Theory
24-809-0913/ 24-809-1013 : Number Theory
24-809-0914/ 24-809-1014 : Representation Theory Of Finite Groups
24-809-0915/ 24-809-1015 : Algebraic Topology
24-809-0916/ 24-809-1016 : Differential Geometry
24-809-0917/ 24-809-1017: Algebraic Graph Theory
24-809-0918/ 24-809-1018 : Wavelets
24-809-0919/ 24-809-1019 : Advanced Optimization Methods and Machine Learning
24-809-0920/ 24-809-1020 : Commutative Algebra
24-809-0921/ 24-809-1021 : Graph Theory
24-809-0922/ 24-809-1022 : C*-Algebra and Representation Theory
24-809-0923/ 24-809-1023 : Reproducing Kernel Hilbert Spaces
24-809-0924/ 24-809-1024 : Topology II
24-809-0925/ 24-809-1025 : Computational Mathematics Laboratory

Cochin University of Science and Technology
Department of Mathematics

Mathematics Elective Papers

(Semester: 1, 2 and 3)

Departmental / Inderdepartmental Elective

(Offered as a Minor for all students)

Semester I
24-809-0101 - Calculus I

Number of credits: 4
Number of hours per week: 4 hrs
Total No. of Hours: 72 hours

Objective: This course introduces the basic concepts from calculus that are required both in the applied and pure branches of science.

Course Outcome (CO): After completing the course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Evaluate the limit of a function and to do differentiation and integration	Evaluate
CO2	Apply the concepts in calculus to solve problems	Apply
CO3	Understand the basic concepts of calculus.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3			

Prerequisites : Set theory, Operations on sets, functions, The set of natural numbers, Set of integers, Set of rational numbers, Set of real numbers and the set of Complex numbers.

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).
2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).
3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).
4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Real Numbers and the Real Line, Coordinates, Lines, and Increments, Functions, Shifting Graphs, Trigonometric Functions, Rates of Change and Limits, Rules for Finding Limits, Target Values and Formal Definitions of Limits, Extensions of the Limit Concept, Continuity and Tangent Lines.
(Sections: Preliminaries 1, 2, 3, 4, 5, 1.1, 1.2, 1.3, 1.4, 1.5 and 1.6 of Text book 1).

Module 2: The Derivative of a Function, Differentiation Rules, Derivatives of Trigonometric Functions, The Chain Rule, Implicit Differentiation and Rational Exponents.
(Sections 2.1, 2.2, 2.4, 2.5 and 2.6 of Text book 1).

Module 3: Extreme Values of Functions, The Mean Value Theorem, The First Derivative Test for Local Extreme Values, Graphing with y' and y''.
(Sections 3.1, 3.2, 3.3 and 3.4 of Text book 1).

Module 4: Indefinite Integrals, Differential Equations, Integration by Substitution-Running the Chain Rule Backward, Riemann Sums and Definite Integrals, Properties, Area, and the Mean Value Theorem, The Fundamental Theorem, Substitution in Definite Integrals.
(Section 4.1, 4.2, 4.3, 4.5, 4.6, 4.7 and 4.8 of Text book 1).

Semester II
24-809-0201 - Calculus II

Number of credits: 4
Number of hours per week: 4 hrs
Total number of Hours: 72 hours

Objective: This course introduces the basic concepts from calculus that are required both in the applied and pure branches of science.

Course Outcome (CO): After completing the course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Evaluate the limit of a function using various rules	Evaluate
CO2	Apply the concepts in calculus to solve problems	Apply
CO3	Understand the basic concepts of sequences and series.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3			

Prerequisites : This course is a continuation of Calculus I course offered in Semester I

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).

2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).

3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).

4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Areas Between Curves, Finding Volumes by Slicing, Volumes of Solids of Revolution, Lengths of Plane Curves.
(Sections: 5.1, 5.2, 5.3 and 5.5 of Text book 1).

Module 2: L Hopital's Rule, Basic Integration Formulas, Integration by Parts, Partial Fraction, Improper Integrals.
(Sections: 6.6, 7.1, 7.2. 7.3 and 7.6 of Text book 1).

Module 3: Limits of Sequences of Numbers, Theorems for Calculating Limits of Sequences.
(Sections: 8.1 and 8.2 of Text book 1).

Module 4: Infinite series, The integral test for series of non negative terms, Comparison tests for series of non negative terms, Ratio and root test for series of non negative terms, Alternating Series, Absolute and Conditional Convergence. (Sections 8.3, 8.4, 8.5, 8.6 and 8.7 of text book 1).

Semester III
24-809-0301 - Calculus III

Number of credits: 4
Number of hours per week: 4 hrs
Total number of Hours: 72 hours

Objective: This course introduces the advanced concepts of calculus that are required both in the applied and pure branches of science.

Course Outcome (CO): After completing the course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Evaluate the limit of a function and to do differentiation and integration	Evaluate
CO2	Apply the concepts in calculus to solve problems	Apply
CO3	Understand the basic concepts of calculus.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3			

Prerequisites : This is a continuation course of Calculus II offered in Semester II.

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).

2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).

3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).

4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Conic Sections and Quadratic Equations, Classification of Conic Section by Eccentricity, Quadratic Equation and Rotations, Parametrization of Plane Curves, Calculus with Parametrized Curves, Polar coordinates, Cylindrical and Spherical coordinates, Vector valued functions and space curves, Arc length and the unit tangent vector, Curvature, torsion and the TNB frame.
(Sections 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, and 10.7 of the text book 1).

Module 2: Functions of several variables, Limits and continuity, Partial derivatives, Differentiability.
(Sections 12.1, 12.2, 12.3 and 12.4 of the text book 1).

Module 3: Linearization and Differentials, The chain rule, Partial derivatives with constrained variables, Directional derivatives, Gradient and tangent planes, Extreme values and saddle points, Lagrange multipliers, Taylor's formula.
(Sections 12.5, 12.6, 12.7, 12.8, 12.9 and 12.10 of the text book 1).

Module 4: Double integrals, Areas, Double integral in polar form, Triple integrals in Rectangular coordinates, Masses, moments in three dimension.
(Sections 13.1, 13.2, 13.3, 13.4 and 13.5 of the text book).

Cochin University of Science and Technology
Department of Mathematics

Mathematics Elective Papers

(Semester: 1, 2 and 3)

Interdepartmental Multidisciplinary Course

(Offered for students not taking Mathematics as major. Can be counted towards minor or multidisciplinary)

Semester I
24-809-0103 - Mathematical Methods I

Number of credits: 3
Number of hours per week: 3 hrs
Total No. of Hours: 54 hours

Objective: This course introduces basic Complex analysis and Differential equations techniques which are important tools in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Understand basic differential equations and know how to solve them.	Understand
CO2	Evaluate complex integrals and higher order complex derivatives	Evaluate

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		

Prerequisites: Basic theory, formulas and techniques of differential and integral calculus of one variable.

Text book:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition. John Wiley and Sons, Inc., New York, (1999).

Reference books:

1. Calculus, Vol I (Second Edition), Tom M. Apostol, Wiley Student Edition, (2006).
2. Calculus and Analytic Geometry (Ninth Edition), George.B.Thomas and Ross.L.Finney, Pearson Education, Inc, (2006)
3. Complex variables and Applications (5th Edition) , J. W. Brown, R.V. Churchill, McGrawHill Higher Education, (1990).
4. Complex Analysis (3rd edition), L.V. Ahlfors, McGrawHill Book Company, (1979).

Syllabus

Module 1: Basic concepts and ideas, Geometric meaning, Exact equations, Linear differential equations, Applications Homogeneous Linear differential equations of second order.
(Chapter 1, Section 2.1 of Text book 1).

Module 2: Homogeneous Linear differential equations of second order with constant coefficients, Euler Cauchy equations, Existence and uniqueness theory, Wronskian, Non homogeneous

equations, Solutions by undetermined coefficients and by variation of parameters.
(Sections 2.2-2.3, Sections 2.6-2.10 of Text book 1).

Module 3: Complex Numbers, Polar form, Analytic Function, Cauchy-Riemann Equations, Elementary Functions, logarithm. Complex Integration, Cauchy's Integral Theorem and Integral Formula (without proof), Higher Derivatives (without proof).
(Section 12.1-12.4, 12.6-12.8, 13.1-13.4 of Text Book 1).

Semester II
24-809-0203 - Mathematical Methods II

Number of credits: 3
Number of hours per week: 3 hrs
Total No. of Hours: 54 hours

Objective: This course introduces Laplace Transform and Fourier series which are important tools in all branches of science. Also, Numerical Methods in General, Numerical Methods in Linear Algebra and Numerical Methods for Differential Equations are introduced. This course also introduces the abstract concept of Groups which is useful in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know Laplace Transform and Fourier series and their applications to various branches.	Remember
CO2	Apply numerical techniques for interpolation, integration and differentiation	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	
CO2	3			

Prerequisites: Basic theory, formulas and techniques of differential and integral calculus of one variable.

Text books:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition. John Wiley and Sons, Inc., New York, (1999).

Reference books:

1. Calculus, Vol I (Second Edition), Tom M. Apostol, Wiley Student Edition, (2006).
2. Calculus and Analytic Geometry (Ninth Edition), George.B.Thomas and Ross.L.Finney, Pearson Education, Inc, (2006)
3. Complex variables and Applications (5th Edition) , J. W. Brown, R.V. Churchill, McGrawHill Higher Education, (1990).
4. Complex Analysis (3rd edition), L.V. Ahlfors, McGrawHill Book Company, (1979).
5. Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, 2017.

Syllabus

Module 1: Power Series, Power series representation of Analytic functions,Taylor series and Maclaurin series, Practical methods for power series. Laplace Transform, Transforms of Derivatives and integrals, Second Shifting theorem.
(Section 14.2-14.5, 5.1-5.3 of Text Book 1).

Module 2: Periodic functions, Fourier Series, Functions of any period, Half-Range Expansion, Fourier Series (Contd.): Complex Fourier Series, Forced Oscillations, Fourier Transform. (Section 10.1-10.10 of Text Book 1).

Module 3: Introduction, Solution of Equations by Iteration, Interpolation, Spline Interpolation, Numeric Integration and Differentiation, Linear Systems: Gauss Elimination (Section 17.1-17.5 of the Text Book)

Semester III
24-809-0303 - Matrix Theory and Graph Theory

Number of credits: 3
Number of hours per week: 3 hrs
Total No. of Hours: 54 hours

Objective: This course introduces the basic concepts from linear algebra and Graph Theory that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know the fundamental concepts of linear algebra and graph theory.	Remember
CO2	Apply the basic results in linear algebra and graph theory for problem-solving.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	2	1	

Text books:

1 Advanced Engineering Mathematics, Erwin Kreyszig, 10th Edition. John Wiley and Sons, Inc., New York, (2011).

2 John Clark Derek Allen Holton - A first look at graph theory, Allied Publishers, 1991.

Reference books:

1 S. Kumaresan: *Linear Algebra: A Geometric Approach*, PHI Learning, 2009.

2 Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.

3 R Balakrishnan and K Ranganathan: *A Text Book of Graph Theory*, Springer.

Syllabus

Module 1: Matrices, Vectors: Addition and Scalar Multiplication, Matrix Multiplication, Linear Systems of Equations, Gauss Elimination, Linear Independence, Rank of a Matrix, Vector Space, Solutions of Linear Systems: Existence, Uniquenes.
(Sections 7.1-7.5 of Text book 1).

Module 2: Determinants, Cramer' s Rule, Inverse of a Matrix, Gauss–Jordan Elimination, The Matrix Eigenvalue Problem, Determining Eigenvalues and Eigenvectors, Some Applications of Eigenvalue Problems, Symmetric, Skew-Symmetric, and Orthogonal Matrices.
(Sections 7.7, 7.8, 8.1 - 8.3 of Text book 1).

Module 3: An introduction to graph: Definition of a Graph, More definitions, Vertex Degrees, Sub graphs, Paths and cycles, the matrix representation of graphs. Trees. Definitions and Simple properties, Bridges, Spanning trees, Cut vertices and Connectivity, Euler's Tours, the Chinese postman problem, Hamiltonian graphs, The travelling salesman problem.
(Sections 1.1 - 1.7, 2.1 - 2.3, 2.6, 3.1 - 3.4 of Text book 2)

Cochin University of Science and Technology
Department of Mathematics

Mathematics Core Papers

(Semester: 1 - 6)

Core papers

(Offered for students opting Mathematics as Major or Minor)

Semester I
24-809-0102 - Basic Analysis I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the structure of Natural Numbers. This course is planned to introduce the notions real number system, Convergence of sequence and series.

Learning Outcomes: After completing the course students will be able to

No.	Course Outcome	Cognitive level
CO1	Know basics of calculus and important notions on the set of real numbers.	Remember
CO2	Understand sequence of real numbers and evaluate their convergence.	Understand
CO3	Apply limit theorems and series convergence tests.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

UNIT 1: Introduction to Natural numbers and Rational Numbers, The set of all Real numbers, Completeness axiom (Sections 1, 2, 3 and 4)

UNIT 2: Extended real number system.Limit of sequence (Sections 5, 6, 7 and 8)

UNIT 3: Limit theorems, Monotone Sequences and Cauchy Sequences (Sections 9, and 10)

UNIT 4: Subsequences, Limsup's and Liminf's, Series (Sections 11, 12 and 14)

UNIT 5: Alternating Series and Integral Tests, Continuous functions, Properties of continuous functions (Sections 15, 17 and 18)

Text Book: Kenneth A. Ross Elementary Analysis: The Theory of Calculus, Second Edition, Springer-Verlag (2013).

References:-

1. Terence Tao, Analysis I and II, Third Edition, Springer 2016.

2. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, Fourth Edition, Wiley India Edition (2011).

3. N.L Carothers, Real Analysis, Wiley 2000.

4. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).

5. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).

6. A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).

7. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).

8. S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)

Semester II
24-809-0202 - Basic Analysis II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the notion of continuous functions. This course is planned to introduce the notions continuity, Convergence of sequence and series of functions and some metric space notions.

Learning Outcomes: After the completion of the course the students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand the notions of limit, continuity and uniform continuity of functions.	Understand
CO2	Understand power series, their convergence, integration and differentiation.	Understand
CO3	Know basic properties and results of derivatives.	Remember
CO4	Know the basics of Riemann integration.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			

UNIT 1: Uniform Continuity, Limit of functions, Power Series (Sections 19, 20 and 23)

UNIT 2: Uniform Convergence, More on Uniform Convergence, Differentiation and Integration of Power Series (Sections 24, 25 and 26)

UNIT 3: Basic Properties of the Derivative, The Mean Value Theorem (Sections 28 and 29)

UNIT 4: L'Hospital's Rule, Taylor's Theorem (Sections 30 and 31)

UNIT 5: The Riemann Integral, Properties of the Riemann Integral, Fundamental Theorem of Calculus (Sections 32, 33 and 34)

Text Book: Kenneth A. Ross Elementary Analysis: The Theory of Calculus, Second Edition, Springer-Verlag (2013).

References:-

1. Terence Tao, Analysis I and II, Third Edition, Springer 2016.

2. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, Fourth Edition, Wiley India Edition (2011).

3. N.L Carothers, Real Analysis, Wiley 2000.

4. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).

5. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).

6. A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).

7. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).

8. S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)

Semester III
24-809-0302 - Matrix Theory I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the basic concepts from linear algebra that are required in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Understand the fundamental concepts and applications of linear algebra.	Understand
CO2	Know how to use the computer software MATLAB.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	2	1	2

Text books:

1 Ron Larson: *Elementary Linear Algebra*, 8th Edition, Cengage Learning, 2016.

Reference books:

1 S. Kumaresan: *Linear Algebra: A Geometric Approach*, PHI Learning, 2009.

2 Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.

3 Michael Artin: *Algebra*, Pearson Prentice Hall, . Linear Algebra: A First Course with Applications

Syllabus

Module 1: Introduction to Systems of Linear Equations, Gaussian Elimination and Gauss-Jordan Elimination, Applications of Systems of Linear Equations, Computational Aspects using computer software MATLAB.
(Sections 1.1 - 1.3 of Text book 1).

Module 2: Operations with Matrices, Properties of Matrix Operations, The Inverse of a Matrix, Elementary Matrices, Computational Aspects using computer software MATLAB.
(Sections 2.1 - 2.4 of Text book 1).

Module 3: Markov Chains, More Applications of Matrix Operations, The Determinant of a Matrix, Determinants and Elementary Operations, Computational Aspects using computer software MATLAB.
(Sections 2.5,2.6, 3.1, 3.2 of Text book 1)

Module 4: Properties of Determinants, Applications of Determinants, Vectors in R^n, Vector Spaces, Subspaces of Vector Spaces, Computational Aspects using computer software MATLAB.
(Sections 3.3, 3.4, 4.1 to 4.3 of Text book 1).

Module 5: Spanning Sets and Linear Independence, Basis and Dimension, Rank of a Matrix and Systems of Linear Equations, Computational Aspects using computer software MATLAB. (Sections 4.4 to 4.6 of Text book 1).

Semester IV
24-809-0401 - Basic Group Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the basic concepts from algebra that are required in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Understand the fundamental concepts and applications of algebra.	Understand
CO2	Know how to use the computer algebra system GAP.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	
CO2	3	1		2

Text books:

1 Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, year.

Reference books:

1 M. Artin: *Algebra*, Pearson Prentice Hall, 2007.

2 J.B. Fraleigh: *A first Course in Abstract Algebra*, Seventh Edition, Pearson, 2014.

3 M.A. Amstrong: *Groups and Symmetry*, Springer, 1997.

4 I.N. Herstein: *Topics in Algebra*, Wiley, 2006.

Syllabus

Module 1: Introduction to Groups: Symmetries of a Square, The Dihedral Groups; **Groups:** Definition and Examples of Groups, Elementary Properties of Groups, Exercises using Computer Algebra System GAP. (PART 2 Chapters 1, 2 of Text book 1).

Module 2: Finite Groups; Subgroups: Subgroup Tests, Examples of Subgroups, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 3 of Text book 1).

Module 3: Cyclic Groups: Properties of Cyclic Groups, Classification of Subgroups of Cyclic Groups, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 4 of Text book 1)

Module 4: Permutation Groups: Cycle Notation, Properties of Permutations, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 5 of Text book 1)

Module 5: Isomorphisms Definition and Examples, Cayley's Theorem, Properties of Isomorphisms, Automorphisms, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 6 of Text book 1)

Semester IV
24-809-0402 - Matrix Theory II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course serves as a second course in linear algebra as a continuation of the Matrix Theory I course.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Understand in depth fundamental concepts and applications of linear algebra.	Understand
CO2	Know in detail the computer software MATLAB.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	
CO2	3	2	1	2

Text books:

1 Ron Larson: *Elementary Linear Algebra*, 8th Edition, Cengage Learning, 2016.

Syllabus

Module 1: Review of Vector space, Applications of Vector Spaces, Inner Product Spaces, Computational Aspects using computer software MATLAB.
(Sections 4.7 - 4.8, 5.1-5.2 of Text book 1).

Module 2: 5.3 Orthonormal Bases, Gram-Schmidt Process, Mathematical Models and Least Squares Analysis, Applications of Inner Product Spaces, Computational Aspects using computer software MATLAB.
(Sections 5.3 - 5.5 of Text book 1).

Module 3: 6.1 Introduction to Linear Transformations, The Kernel and Range of a Linear Transformation, Matrices for Linear Transformations, Computational Aspects using computer software MATLAB.
(Sections 6.1-6.3 of Text book 1)

Module 4: Transition Matrices and Similarity, Applications of Linear Transformations Eigenvalues and Eigenvectors, Computational Aspects using computer software MATLAB.
(Sections 6.4, 6.5 and 7.1 of Text book 1).

Module 5: Diagonalization, Symmetric Matrices and Orthogonal Diagonalization, Applications of Eigenvalues and Eigenvectors, Computational Aspects using computer software MATLAB.
(Sections 7.2 to 7.4 of Text book 1).

References:-

1. Arindama Singh: *Introduction to Matrix Theory*, Springer, 2021.

2. Kenneth Hoffman and Ray Kunze *Linear Algebra*, Second Edition, PHI (1975).

3. M. Artin, Algebra, Prentice-Hall, (1991)

4. Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.

5. S.Kumaresan, *Linear Algebra: A Geometric Approach*, Fist Edition PHI Learning (2009).

6. Sheldon Axler, *Linear Algebra Done Right*, Second Edition, Springer, (1997).

Semester IV
24-809-0403 - Elementary Complex Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the concepts and results from complex variable theory that are required for further study of advanced mathematics.

Outcome: After completing the course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand the fundamental notions of complex functions and their mappings.	Understand
CO2	Evaluate the continuity and differentiability of complex functions.	Evaluate
CO3	Know Analytic functions with examples.	Understand
CO4	Evaluate definite integrals of functions and contour integrals.	Evaluate

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3			
CO4	3	1		

Prerequisites Basic familiarity with formulas and techniques of differential and integral calculus

Text books:

1 J. W. Brown and R. V. Churchill, Complex Variables and Applications (8th Edition), Mcgraw-Hill,(2009).

Reference books:

1 L. V. Ahlfors, Complex Analysis, Mcgraw-Hill, 1980.

2 J. B. Conway, Functions of One Complex Variable (2nd Edition), Springer-Verlag, 1978.

3 R. Greene and S. G. Krantz, Function Theory of One Complex Variable, 3rd Edition, GSM, Vol. 40, AMS, 2006

4 T. W. Gamelin, Complex Analysis, Springer-Verlag, 2001.

5 S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser Boston, 2006.

Syllabus

Module 1. Sums and products, Basic Algebraic Properties, Further Properties, Vectors and Moduli, Complex conjugates, Exponential Form, Products and Power in Exponential Form, Argument of Products and Quotients, Roots of Complex Numbers, Examples, Regions in the Complex plane. (Sections 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 of the text book 1).

Module 2. Functions of Complex Variable, Mappings, Mappings by the Exponential Function, Limits, Theorems of Limits, Limits Involving the Point at Infinity. (Sections 12, 13, 14, 15, 16 and 17 of the Text book 1).

Module 3. Continuity, Derivatives and Differentiation Formulas. Cauchy-Riemann Equations, Sufficient Conditions for Differentiability, Polar Coordinates. (Sections 18, 19, 20, 21, 22 and 23 of the text book 1).

Module 4. Analytic Functions, Examples and Harmonic Functions. The Exponential Function, The Logarithmic Function, Some Identities Involving Logarithms, Complex Exponents, Trigonometric Functions Hyperbolic Functions. (Sections 24, 25, 26, 29, 30, 32, 33, 34 and 35 of the text book 1).

Module 5. Derivatives of Functions w(t), Definite Integrals of Functions w(t), Contours, Contour Integrals, Some Examples. Upper Bounds for Moduli of Contour Integrals, Antiderivatives and Cauchy–Goursat Theorem. (Sections 33, 37, 38, 39, 40, 41 43, 44, and 46 of the text book 1).

Semester IV
24-809-0404 - Basics in Python Programming

Number of credits: 3
Number of hours per week: 4 hrs
Total number of Hours: 72 hours

Objective: This course introduces the basics in python programming that are required in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know the fundamentals in python programming	Remember
CO2	Apply Python programs in other branches of study.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	2
CO2	3	3	1	3

Text books:

1 Kaswan, K. S., Dhatterwal, J. S. and Balamurugan, B. (2023). Python for Beginners. CRC Press.

2 Fuhrer, C., Solem, J. E., Verdier, O. (2021). Scientific Computing with Python: High-performance scientific computing with NumPy, SciPy, and pandas. Packt Publishing Ltd.

Reference books:

1 Langtangen, H. P. (2016). A primer on scientific programming with Python. Springer-Verlag Berlin Heidelberg.

2 Charles Dierbach, "Introduction to Computer Science Using Python: A Computational Problem-Solving Focus", Wiley, 2013.

3 Kenneth A Lambert., Fundamentals of Python : First Programs, 2/e, Cengage Publishing,2016

4 Mark Lutz, 'Learning Python', 5th Edition, O'Reilly Media, Inc.

Syllabus

Module 1: Introduction- Python Software setup, Datatypes, Sequence types, special types, Operators and Operands, Input and Output Functions, Flow control statements
(Sections 1.6, 2, 3.1, 4.3-4.6, 5.1, 5.3, 5.4 of Text 1).

Module 2: Functions, Lambda, Modules, List Comprehensions, Object Oriented Programming
(Sections 6.1 - 6.8, 7.1 - 7.8, 11.1 - 11.6 of Text 1).

Module 3: Encapsulation, Inheritance, Error and Exception Handling, Numpy
(Sections 11.8- 11.9 of Text 1 & Sections 12.1 - 12.3, 14.1- 14.2 of Text 2)

Module 4: Python for Scientific Computing- Linear Algebra Arrays, Understanding SciPy, Solving Linear System in Python, Building Least square Models and application on Prediction Problems
(Sections 4.1- 4.9 of Text 2).

Module 5: Data Analysis with Pandas, Working with Matplotlib
(Sections 6.1- 6.3, 10.2 - 10.4 Text 2).

Semester V
24-809-0501 - Real Analysis I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course aims to provide the fundamentals of mathematical analysis such as axiomati introduction to the real number system, convergence of sequences and series, notion of continuous functions on metric spaces motivated from the real number system.

Outcome: After completing the course the student will be able to

No.	Course Outcome	Cognitive level
CO1	Know basics of Real Number system and its properties.	Remember
CO2	Understand sequences and series and evaluate their convergence and limits.	Understand
CO3	Understand continuity and uniform continuity of functions.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Text book:

1 R.G. Bartle and D.N. Sherbert, *Introduction to Real Analysis*, Thired Edition, John Wiley & Sons (2000).

Reference books:

1 G.B folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.

2 Elias M. Stein, Rami Shakarchi: *REAL ANALYSIS Measure Theory, Integration, and Hilbert Spaces* Princeton University press.

3 Kenneth A. Ross *Elementary Analysis The Theory of Calculus* Springer-Verlag, New York, 2013.

4 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.

5 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.

6 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1. Sets and Functions, Mathematicle Induction, Finte and Infinite Sets, The Algebraic and Order Properties of $\mathbb{R}$, Absolute Value and Real Line and The completeness Property of $\mathbb{R}$. (Sections 1.1, 1.2, 1.3, 2.1, 2.2 and 2.3 of Text book 1).

Module 2. Applications of the Supremum Property, Intervals, Open and Closed Sets in $\mathbb{R}$, Compact Sets, Continuous Functions and Metric Spaces. (Sections 2.4, 2.5, 11.1, 11.2, 11.3 and 11.4 of Text book 1).

Module 3. Sequences and Their Limits, Limit Theorems, Monotone Sequences, Subsequences and the Bolzano-Weierstrass Theorem, The Cauchy Criterion and Properly Divergent Sequences. (Sections 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 of Text book 1).

Module 4. Introduction to Series, Limits of Functions, Limits Theorems and Some Extensions of Limit Concept. (Sections 3.7, 4.1, 4.2 and 4.3 of Text book 1).

Module 5. Continuous Functions, Combinations of Continuous Functions, Continuous Functions on Intervals, Uniform Continuity, Continuity and Gauges, Monotone and Inverse functions. (Sections 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6 of Text book 1).

Semester V
24-809-0502 - Complex Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the concepts and results from complex variable theory athat is required for further study of advanced mathematics.

Outcome: After completing the course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Know basic theorems of complex integration.	Remember
CO2	Understand power series and their convergence.	Understand
CO3	Comprehend the idea of singular points with examples.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: Basic familiarity with formulas, techniques of differential and integral calculus, Natural Numbers and Integers.
Text books:

1 J. W. Brown and R. V. Churchill, Complex Variables and Applications (8th Edition), Mcgraw-Hill,(2009).

Reference books:

1 L. V. Ahlfors, Complex Analysis, Mcgraw-Hill, 1980.

2 J. B. Conway, Functions of One Complex Variable (2nd Edition), Springer-Verlag, 1978.

3 R. Greene and S. G. Krantz, Function Theory of One Complex Variable, 3rd Edition, GSM, Vol. 40, AMS, 2006.

4 T. W. Gamelin, Complex Analysis, Springer-Verlag, 2001.

5 S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser Boston, 2006.

Syllabus

Module 1. Cauchy Integral Formula, An Extension of the Cauchy Integral Formula, Some Consequences of the Extension, Liouville's Theorem and the Fundamental Theorem of Algebra, Maximum Modulus Principle. (Sections 50, 51, 52, 53 and 54 of the text book 1).

Module 2. Convergence of Sequences, Convergence of Series, Taylor Series, Examples, Laurent Series, Examples. (Sections 55, 56, 57, 59, 60 and 62 of Text book 1).

Module 3. Absolute and Uniform Convergence of Power Series, Continuity of Sums of Power Series, Integration and Differentiation of Power Series, Uniqueness of Series Representations, Multiplication and Division of Power Series, Isolated Singular Points and Residues Cauchy's Residue Theorem, Residue at Infinity. (Sections:63, 64, 65, 66, 67, 68, 69 and 71, of Text book 1).

Module 4. The Three Types of Isolated Singular Points, Residues at Poles, Examples, Zeros of Analytic Functions, Zeros and Poles, Behavior of Functions Near Isolated Singular Points.(Sections: 72, 73, 74, 75, 76 and 77 of Text book 1).

Module 5. Argument Principle, Rouche's Theorem, Linear Transformations, Transformation $w = \frac{1}{z}$, Mapping of $\frac{1}{z}$, Linear fractional transformations, Mapping of the upper half plane. (Sections: 86, 87, 90, 91, 92, 93 and 95 of Text book 1).

Semester V
24-809-0503 - Group Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: The course is devoted to some of the basic concepts and results of Group Theory. This course aims to introduce students to some more sophisticated concepts and results of group theory as an essential part of general mathematical culture and as a basis for further study of more advanced mathematics.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know the fundamental concepts of Group theory.	Remember
CO2	Understand basic results and techniques from the theory of finite groups.	Understand
CO3	Comprehend the symmetries in the Euclidean plane.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	1		

Text books:

1 J.B. Fraleigh: *A first Course in Abstract Algebra*, Seventh Edition, Pearson, 2014.

2 Michael Artin: Algebra, Prentice-Hall India, New Delhi, 2007.

Reference books:

1 M.A. Amstrong: *Groups and Symmetry*, Springer, 1997.

2 Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, 2017.

3 I.N. Herstein: *Topics in Algebra*, Wiley, 2006.

Syllabus

Module 1: Review of group theory: Groups, Subgroups, Cyclic groups.
(Sections 4, 5, 6 of Text Book 1).

Module 2: Generating sets and Cayley digraphs, Groups of Permutations, Orbits, Cycles, Alternating Groups.
(Sections 7, 8, 9 of Text Book 1).

Module 3: Cosets and the Theorem of Lagrange, Direct Products and Finitely Generated Abelian Groups.
(Sections 10, 11, 13 of Text Book 1).

Module 4: Homomorphisms, Factor Groups, Factor-Group Computations and Simple Groups. (Sections 14,15 of Text Book 1).

Module 5: Symmetry: Symmetry of plane figures, The group of motions of the Plane, Finite group of motions.
(Sections 5.1-5.3 of Text Book 2).

Semester V
24-809-0504 - Linear Algebra and Geometry

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the basic concepts from linear algebra and Group Theory that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know basics of linear transformations, orthogonality and hyperplanes.	Remember
CO2	Understand diagonalization and classification of quadrics.	Understand
CO3	Evaluate multiple integrals.	Evaluate
CO4	Apply Stoke's theorem and Green's theorem for integration.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	1		
CO4	3	1		

Text books:

1. S.Kumaresan, *Linear Algebra: A Geometric Approach*, First Edition PHI Learning (2009).
2. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

Reference books:

1. Sheldon Axler: *Linear Algebra Done Right*, 3rd edition. Undergraduate Texts in Mathematics, Springer, Cham, 2015.
2. Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.
3. Michael Artin: *Algebra*, Prentice Hall, Inc., Englewood Cliffs, NJ, 1991.
4. Gilbert Strang: *Introduction to Linear Algebra*, 4th Edition, Wellesley Cambridge Press; 2009.

Syllabus

UNIT 1: Lines and Quotient spaces, Geometric ideas, Some special linear transformations (Chapter 3, Sections 4.5 - 4.6 of Text book 1).

UNIT 2: Orthogonality, Geometricapplications, Orthonormal basis, Hyperplanes, Reflections (Sections 5.2 - 5.9 of Text book 1)

UNIT 3: Diagonalization, Classification of quadrics (Chapter 7, 8 of Text book 1)

Module 4: Triple integral in cylindrical and spherical coordinates, Substitution in Multiple integrals, Line integral, Vector fields, work, circulation and flux, Path independence, Potential functions and conservative fields. (Sections 13.6, 13.7, 14.1, 14.2 and 14.3 of the text book 2).

Module 5: Green's theorem in the plane, Surface area Surface integral, parametrized surface, Stoke's theorem and Divergence theorem. (Sections 14.4, 14.5, 14.6, 14.7 and 14.8 of the text book 2).

Semester VI
24-809-0601 - Real Analysis II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course aims to provide the fundamentals of mathematical analysis: notion of differentiability, The Riemann Integral, sequences and series of functions, uniformconvergence, and the interchange of limit operations and an invitation to the calculus of several real variables.

Outcome: After the completion of this course, student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand basic concepts and theorems of derivatives.	Understand
CO2	Understand Riemann integration.	Understand
CO3	Evaluate convergence and absolute convergence.	Evaluate
CO4	Know basic properties of generalized Riemann integral and Lebesgue integral.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	1		
CO4	3			

Text book:

1 R.G. Bartle and D.N. Sherbert, *Introduction to Real Analysis*, Thired Edition, John Wiley & Sons (2000).

Reference books:

1 G.B folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.

2 Elias M. Stein, Rami Shakarchi: *REAL ANALYSIS Measure Theory, Integration, and Hilbert Spaces* Princeton University press.

3 Kenneth A. Ross *Elementary Analysis The Theory of Calculus* Springer-Verlag, New York, 2013.

4 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.

5 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.

6 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1. The Derivatie, The Mean Value Theorem , L'Hospital Rules and Taylors Theorem. (Sections 6.1, 6.2, 6.3 and 6.4 of Text book 1).

Module 2. The Riemann Integral, Riemann Integrable Functions, The Fundamental Theorem and Approximate Integration. (Sections 7.1, 7.2, 7.3 and 7.4 of Text book 1).

Module 3. Pointwise and Uniform Convergence, Interchange of Limits, The Exponential and Logarithmic Functions and Trigonometric Functions. (Sections 8.1, 8.2, 8.3 and 8.4 of Text book 1).

Module 4. Absolute Convergence, Test for Absolute Convergence, Test for Nonabsolute Convergence and Series of Functions. (Sections 9.1, 9.2, 9.3 and 9.4 of Text book 1).

Module 5. Definition and main properties of Generalized Riemann Integral, Improper and Lebesuge Integrals, Infinite Intervals. (Sections 10.1, 10.2 and 10.3 of Text book 1).

Semester VI
24-809-0602 - Ring Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course aims to introduce students to the basic concepts of ring theory.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know fundamental concepts of Rings and Fields with examples.	Remember
CO2	Understand rings of polynomial and factorization of polynomials over a field.	Understand
CO3	Know Homomorphisms and factor rings.	Remember
CO4	Understand prime and maximal ideals.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			

Text books:

1 J.B. Fraleigh: *A first Course in Abstract Algebra*, Seventh Edition, Pearson, 2014.

Reference books:

1 Michael Artin: Algebra, Prentice-Hall India, New Delhi, 2007.

2 Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, 2017.

3 I.N. Herstein: *Topics in Algebra*, Wiley, 2006.

Syllabus

Module 1: Rings and Fields: Definitions and Basic Properties, Homomorphisms and Isomorphisms, Fields; Integral Domains: Divisors of zero and cancellation, Integral Domain, The Characteristic of a Ring.
(Section 18, 19 of Text Book 1).

Module 2: Fermat's and Euler's Theorems: Fermat's Theorem, Euler's Generalization, Application to Congruence Equations; The Field of Quotients of an Integral Domain: The Construction, Uniqueness.
(Section 20, 21 of Text Book 1).

Module 3: Rings of Polynomials: Polynomials in an Indeterminate, The Evaluation Homomorphisms, Factorization of polynomials over a field: The Division Algorithm in $F[x]$, Irreducible Polynomials, Unique Factorization in $F[x]$.
(Section 22, 23 of Text Book 1).

Module 4: Homomorphisms and Factor Rings: Homomorphisms, Properties of Homomorphisms, Factor Rings, Fundamental Homomorphism Theorem.
(Section 26 of Text Book 1).

Module 5: Prime and Maximal Ideals: Maximal Ideals, Prime Ideals, Prime Fields, Ideal Structure in $F[x]$, Application to Unique Factorization in $F[x]$.
(Section 26, 27 of Text Book 1).

Semester VI
24-809-0603 - Ordinary Differential Equations

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of Ordinary differential equations. Course aims to build an understanding of the classical models in terms of ordinary differential equations and pave the foundations for the study of Integral equations.

Learning Outcomes: After the completion of the course the students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand solving techniques of first order differential equations.	Understand
CO2	Know basics notions of second order linear and partial differential equations.	Remember
CO3	Understand the ideas of initial value problems and analyse the existence and uniqueness of their solution.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2		
CO2	3			
CO3	3	1		1

UNIT 1: A brief introduction, Physical and other models, Review of basics; Uniform convergence, Fixed Point Theorem, Some points in Linear Algebra (Chapter 1, 2 of the Text book)
UNIT 2: First Order Equations, Exact Differential Equations (Chapter 3, Sections 3.1,3.2.)
UNIT 3: Second Order Linear Equations, PDE and ODE (Chapter 3, Sections 3.3-3.6.)
UNIT 4: General Theory of Initial Value Problems; Well-posed problems, Uniqueness Theorem (Chapter 4, Sections 4.1-4.2.)
UNIT 5: Existence and Uniqueness Theorems, Continuous dependance of solution on initial data and dynamics (Chapter 4, Sections 4.3-4.8.)
Text Book:

1. A. K. Nandakumaran; P. S. Datti; Raju K. George, *Ordinary Differential Equations; Principles and Applications*, Cambridge University Press, IISc Series 2017.

References:-

1. Peter J. Collins, *Differential and Integral Equations*, Oxford University Press,(2006).
2. Carmen Chicone, *Ordinary Differential Equations with Applications*, Springer (2006).
3. George F. Simmons, *Differential Equations with Applications and Historical Notes*, Tata McGraw-Hill, Third Editon 2003.
4. Michael D. Greenberg, *Ordinary Differential Equations*, Wiley (2012).
5. Michael E. Taylor, *Introduction to Differential Equations*, AMS (2011).
6. Vladimir I. Arnol'd, *Ordinary Differential Equations*, Springer (1992).
7. Earl A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications, New york, (1961).

Cochin University of Science and Technology
Department of Mathematics

Mathematics – Elective Papers

(Semester: 5 and 6)

Departmental Elective

(Offered for students opting Mathematics as Major or Minor)

Semester V or VI: 24-809-0505 / 24-809-0605 - Discrete Mathematics

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours
Objective: This course gives a thorough introduction to Discrete Mathematics with rigorous mathematics and serves as the basis for further studies in this area.

Outcome: After completing the course, the student will be able to

No.	Course Outcome	Cognitive level
CO1	Know basic terminologies and ideas of graph theory.	Remember
CO2	Know important ideas of counting and notions of lattices and ordered sets.	Remember
CO3	Understand the fundamental concepts of Boolean algebra.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			1

Text books:

1. John Clark Derek Allen Holton - A first look at graph theory, Allied Publishers, 1991.
2. Seymour Lipschutz - Discrete Mathematics, Tata McGraw Hill, 1997.

Module 1: Introduction to Graph Theory
Graph Theory. An introduction to graph. Definition of a Graph, More definitions, Vertex Degrees, Sub graphs, Paths and cycles, the matrix representation of graphs.
Text 1: Chapter 1 (Sections 1.1, 1.3 to 1.7)

Module 2: Trees and connectivity
Trees. Definitions and Simple properties, Bridges, Spanning trees. Cut vertices and Connectivity. Euler's Tours, the Chinese postman problem. Hamiltonian graphs and the travelling salesman problem.
Text 1: Chapter 2 (Sections 2.1, 2.2, 2.3, 2.6); Chapter 3 (Sections 3.1 (algorithm deleted), 3.2 (algorithm deleted), 3.3, and 3.4 (algorithm deleted))

Module 3: Counting
Counting, Basic counting principles, Permutations, Combinations, Pigeon-hole principle, Inclusion-exclusion principle, Ordered-unordered partitions.
Text 2: Chapter 6 (Sections 6.1-6.8)

Module 4: Language, Grammars and Machine - Lattices and Ordered Sets
Languages, Grammars, Machines languages, Regular languages, Finite state automata, Finite state machines, ordered sets, Lattices distributive lattices.
Text 2: Chapters 13 and 14 (Sections 13.1-13.7; 14.1-14.11)

Module 5: Boolean Algebra
Boolean algebra, Representation theorem, Minimal boolean expressions, Logic gates, boolean functions.
Text 2: Chapter 15 (Sections 15.1-15.11)

Semester V or VI: 24-809-0506 / 24-809-0606 - Linear Programming

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: Linear Programming is perhaps the most recognized and widely used optimization tool in the world today. It has its origins in planning and operations models from World War II through the seminal work of George Dantzig and his development of the simplex method. In this course, the student will learn how to model real world problems as linear programs, and will learn various methods to solve them.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know solution techniques of LP problems geometrically and more effectively using Simplex algorithm.	Remember
CO2	Understand duality theory, a theory that establishes relationships between linear programming problems of maximization and minimization.	Understand
CO3	Know how to solve transportation and assignment problems.	Apply
CO4	Know how to determine the shortest path, critical path and maximal flow in a network.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2		1
CO2	3			
CO3	3	2	2	2
CO4	3	2	2	1

Pre-Requisite : Elementary Linear Algebra and basic Calculus.

Text books:

1. K.V. Mital; C. Mohan: Optimization methods in operations, Research and systems analysis (3rd Edn.), New age international (P) Ltd., 1996.

References:-

1. A. Ravindran, D.T. Philips and J.J. Solberg: Operations Research-Principles and Practices (2nd Edn.); John Wiley & Sons, 2000

2. G. Hadley: Linear Programming; Addison-Wesley Pub Co Reading, 1975.

3. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall of India, 2000.

4. H.S. Kasana and K.D. Kumar: Introductory Operations Research-Theory and Applications, Springer-Verlag, 2003.

5. James K. Strayer: Linear Programming and Its Applications,Under graduate Texts in Mathematics Springer (1989), Springer-Verlag, 2003.

6. R. Panneerselvam: Operations Research, PHI, New Delhi (Fifth printing), 2004.

Module 1: Mathematical Preliminaries
Euclidean Space, Linear Algebraic functions, Convex Sets. (Chapter 1 (1.1-1.19) of the text).

Module 2: : Linear Programming
Introduction – Degeneracy. (Chapter 3 (3.1-3.14) of the text).

Module 3: Linear Programming (continued)
Simplex multipliers – Dual simplex method. (Chapter 3 (3.15-3.20) of the text).

Module 4:
Transportation and Assignment problems. (Chapter 4 (4.1 – 4.15) of the text).

Module 5:
Flow and potential in networks. (Chapter 5 (5.1 – 5.9) of the text).

Semester V or VI: 24-809-0507 / 24-809-0607: Elements of Applied Mathematics

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the structure of $\mathbb{C}^n$ and it is planned to introduce the Discrete Fourier Transformation in a Linear algebraic perpsective. Towards the end Differece calculus and solution of Linear and Non Linear difference equations will be discussed.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the necessary tools in applied mathematics in a signal processing perspective.	Apply
CO2	Understand the theory revolving signal processing based around transforms.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3		1	
CO2	3			

Pre-Requisite : Review of sections $1.1, 1.2, 1.3$ of the text 1.

Text Book:

1. Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer-Verlag New York, (1999).

2. Walter G. Kelley & Allan C. Peterson Difference Equations An Introduction with Applications, Second Edition, Academic Press 2001.

References:-

1. Stephane Mallat, *A Wavelet Tour Of Signal Processing*, Academic Press (1999).

2. Don Hong, Jianzhong Wang, Robert Gardner, *Real Analysis with an Introduction to Wavelets*, Elsevier Academic Press (2005).

3. Ronald. E.Mickens, Difference Equations: Theory, Applications and Advanced Topics, Third Edition, Chapman and Hall, 2015.

UNIT 1: Diagonalization of Linear Transformations and Matrices, Inner products, Orthonormal Bases and Unitary Matrices. (Chapter 1, Sections 1.5, 1.6 of the text 1.)

UNIT 2: The Discrete Fourier Transform, Translation-Invariant Linear Transformations (Chapter 2, Sections 2.1, 2.2 of the text 1.)

UNIT 3: The Fast Fourier Transform, Introduction, The Difference Operator, Summation, Generating Functions and Approximate summation. (Section 2.3 of text 1, Chapters 1, 2 of the text 2.)

UNIT 4: Linear Difference Equations, First Order Equations, General Results for Linear Equations, Solving Linear Equations, Applications. (Chapter 3, Sections 3.1, 3.2, 3.3, 3.4 of the text 2.)

UNIT 5: Equations with Variable Coefficients, Nonlinear Equations That Can Be Linearized, The z-Transform. (Chapter 3 sections 3.5, 3.6, 3.7 of text 1.)

Semester V or VI: 24-809-0508 / 24-809-0608: Introduction to Optimization Techniques

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: The objective of this course is to introduce different classes of optimization problems following some classical methods to solve them. Starting with methods to solve Linear Programming problem, different direct and indirect methods to solve Non-linear Programming problems are also discussed in this course. This course also includes solution methods for constrained and unconstrained optimization problems.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Evaluate the optimization problems and classify them based on objective function and constraints.	Evaluate
CO2	Apply the knowledge of different optimization methods to solve an optimization problem efficiently.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3		1	
CO2	3	2	2	2

Pre-Requisite : Calculus and Linear Algebra.

Text books:

1. "Engineering Optimization: Theory and Practice" by Singiresu S. Rao (Fourth Edition).

References:-

1. "Optimization for Engineering Design Algorithms and Examples" by Kalyanmoy Deb.

Module 1: Introduction to Optimization
Introduction, Statement of an Optimization Problem, Classification of Optimization Problems. (Sec 1.1,1.4,1.5).

Module 2: : Classical Optimization Techniques
Single-Variable Optimization, Multivariable Optimization with No Constraints, Multivariable Optimization with Equality Constraints, Multivariable Optimization with Inequality Constraints, Convex Programming Problem. (Sec 2.1-2.6).

Module 3: Linear Programming
Standard Form of a Linear Programming Problem, Simplex Algorithm, Duality in Linear Programming, Transportation Problem, Karmarkar's Interior Method, Quadratic Programming. (Sec 3.3, 3.8, 3.9, 4.3, 4.6, 4.7, 4.8).

Module 4: Nonlinear Programming: Unconstrained Optimization Techniques
Random Search Methods, Grid Search Method, Univariate Method, Pattern Directions, Powell's Method, Steepest Descent (Cauchy) Method, Conjugate Gradient (Fletcher–Reeves) Method,

Newton's Method, Marquardt Method, Quasi-Newton Methods, DFP Method, BFGS Method. (Sec 6.2-6.6, 6.8-6.15).

Module 5: Nonlinear Programming: Constrained Optimization Techniques
Random Search Methods, Complex Method, Sequential Linear Programming, Basic Approach in the Methods of Feasible Directions, Zoutendijk's Method of Feasible Directions, Rosen's Gradient Projection Method, Sequential Quadratic Programming, Penalty Function Method, Convex Programming. Problem. (Sec 7.9-7.8, 7.10-7.15).

Semester V or VI: 24-809-0509 / 24-809-0609: Metric Topology

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: The aim is to give a very streamlined development of a course in metric space topology emphasizing only the most useful concepts, concrete spaces and geometric ideas. To encourage the geometric thinking. In this course there are large number of examples which allow us to draw pictures and develop our intuition and draw conclusions, generate ideas for proofs. To this end, this course boasts of a lot of pictures. A secondary aim is to treat this as a preparatory ground for a general topology course and arm the reader with a repertory of examples.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know fundamental ideas revolving around limit and continuity.	Remember
CO2	Understand the notions of compactness and connectedness with examples.	Understand
CO3	Know in depth, completeness property and spaces that serve as examples.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: Introductory course in real analysis.
Text books:

1 S. Kumaresan, *Topology of Metric Spaces*, Alpha Science International Ltd, 2005.

Reference books:

1 G.B. Folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.

2 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.

3 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.

4 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1: Review of Definition and Examples of Open Balls and Open Sets, Convergent Sequences, Limit and Cluster Points, Cauchy Sequences and Completeness, Bounded Sets, Dense Sets, Basis and Boundary of a Set. (Chapter 2 of Text book 1).

Module 2: Continuous Functions, Equivalent Definitions of Continuity, Topological Property, Uniform Continuity, Limit of a Function, Open and closed maps. (Chapter 3 of Text book 1).

Module 3: Compact Spaces and their Properties, Continuous Functions on Compact Spaces, Characterization of Compact Metric Spaces and Arzela-Ascoli Theorem. (Chapter 4 of Text book 1).

Module 4: Connected Spaces, Path Connected spaces. (Chapter 5 of Text book 1).

Module 5: Examples of Complete Metric Spaces, Completion of a Metric Space, Baire Category Theorem and Banach's Contraction Principle. (Chapter 6 of Text book 1).

Semester V or VI: 24-809-0510 / 24-809-0610: Fuzzy Mathematics

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course gives a thorough introduction to Fuzzy Mathematics with an extension to how crisp concepts can be fuzzified through introducing the concept of Fuzzy Graphs.

Outcome: After the completion of the course the student will be able to

No.	Course Outcome	Cognitive level
CO1	Know the fundamental concepts of fuzzy sets and fuzzy arithmetic.	Remember
CO2	Understand the idea of fuzzy logic.	Understand
CO3	Know fuzzy graphs and their basic properties.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Text books:

1 George J. Klir and BoYuan, Fuzzy Sets and Fuzzy Logic Theory and Applications, Prentice Hall of India Private Limited New Delhi, 2000.

2 Sunil Mathew, John N Mordeson, Davender S Malik, Fuzzy Graph Theory, Springer, 2018.

Reference books:

1 Klir, G. J and T. Folger, Fuzzy Sets, Uncertainty and Information, Prentice Hall of India Private Limited New Delhi, 1988.

2 H.J Zimmermann, Fuzzy Set Theory- and its Applications, Allied Publishers, 1996.

3 Dubois, D and H. Prade , Fuzzy Sets and System: Theory and Applications, Academic Press, New York, 1988.

4 Abraham Kandel, Fuzzy Mathematical Techniques with Applications, Addison Wesley Publishing Company 1986.

Syllabus

Module 1: Crisp sets to Fuzzy sets
Introduction , Crisp Sets: An Overview ,Fuzzy Sets: Basic Types ,Fuzzy Sets: Basic concepts. Additional properties ofalpha cuts, Representation of fuzzy sets.
(Chapter 1: 1.1, 1.2, 1.3 and 1.4 and Chapter 2: 2.1 , 2.2 of Text 1).

Module 2: Operations on Fuzzy Sets
Types of Operations, Fuzzy complements, Fuzzy intersections: t-norms, Fuzzy Union, t-conorms, Combinations of operations.
(Theorems 3.7, 3.8,3.11,3.13, 3.16 and 3.18 statement only)
(Chapter 3: 3.1, 3.2, 3.3, 3.4, 3.5 of Text 1).

Module 3: Fuzzy Arithmetic
Compact Fuzzy numbers, Arithmetic operations on Intervals, Arithmetic operations on Fuzzy numbers. (Exclude the proof of Theorem 4.2), Fuzzy equations.
(Chapter 4: 4.1, 4.3, 4.4 and 4.6 of Text 1).

Module 4: Fuzzy Logic
Classical Logic: An Overview, Multivalued Logics, Fuzzy propositions, Fuzzy quantifiers, Linguistic Hedges, Inference from Conditional Fuzzy propositions.
(Chapter 8: 8.1, 8.2, 8.3, 8.4, 8.5 and 8.6 only of Text 1).

Module 5: Fuzzy Graphs
Fuzzy Graphs: Definitions and Basic Properties, Connectivity in Fuzzy Graphs, Forests and Trees, Fuzzy Cut Sets.
(Chapter 2: 2.1, 2.2, 2.3, 2.4 of Text 2).

Semester V or VI: 24-809-0511 / 24-809-0611: Introduction to Optimization in Machine Learning

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces relevant aspects of linear algebra and how these concepts are related to optimization in machine learning.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Apply Linear Algebra in Machine learning	Apply
CO2	Understand how the concepts of linear algebra are related to optimization methods used in machine learning.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2		2
CO2	3	2	2	1

Text books:

1 Aggarwal, C. C., Aggarwal, L. F., & Lagerstrom-Fife. (2020). Linear algebra and optimization for machine learning (Vol. 156). Springer International Publishing.

Reference books:

1 Boyd, S., Boyd, S. P., & Vandenberghe, L. (2004). Convex optimization. Cambridge university press.

2 Noble, B., & Daniel, J. W. (1977). Applied linear algebra (Vol. 477). Englewood Cliffs, NJ: Prentice-Hall

3 Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. MIT press

4 Strang, G. (2019). Linear algebra and learning from data (Vol. 4). Cambridge: Wellesley-Cambridge Press.

5 Strang, G. (2016). Introduction to Linear Algebra (5th Edition). Wellesley Publishers (India), ISBN : 978-09802327-7-6.

Syllabus

Module 1: Introduction to Optimization, Scalars, Vectors and Matrices, Matrix Multiplication on Decomposible Operator, Matrix Factorization.
(Sections 1.1- 1.3, 1.4.1 of Text 1).

Module 2: Basic Problems in Machine Learning- Clustering, classification and Regression Modelling, Outlier Detection, Optimization for Machine Learning
(Sections 1.4-1.5 of Text 1).

Module 3: Geometry of Matrix Multiplication, Vector Spaces and their Geometry, Basis, Rank of a Matrix, Effect of Matrix Operations on Rank, Generating Orthogonal Basis sets
(Sections 2.1- 2.3, 2.6-2.7 of Text 1)

Module 4: An Optimization- centric view of Linear Systems, Determinants, Diagonalizable transformations and Eigenvectors, Fast Matrix Operations in Machine Learning, Diagonalizable matrices in Machine Learning
(Sections 2.8, 3.2-3.3, 3.4.1- 3.4.2 of Text 1).

Module 5: Symmetric Matrices in Quadratic Optimization, Variable Separation for Optimization, Numerical Algorithms for Finding Eigen vectors, Basics of Optimization
(Sections 3.4.3- 3.4.5, 3.5, 4.2 of Text 1).

Semester V or VI: 24-809-0512 / 24-809-0612: Elementary Number Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: Number theory is one of the oldest and most mysterious parts of mathematics. This course will give an introduction to the area of Number Theory.

Outcome: After completing the course, students will be equipped to

No.	Course Outcome	Cognitive level
CO1	Know fundamental principles of Number Theory	Remember
CO2	Know the concepts of convergence and theorems related to it.	Remember
CO3	Know quadratic reciprocity and quadratic convergence with composite moduli.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: Basic familiarity with formulas, techniques of differential and integral calculus, Natural Numbers and Integers.
Text books:

1 D. M. Burton, Elementary Number Theory, 7th Ed., McGraw Hill, 2017.

Reference books:

1 I. Niven, S. Zuckerman and H. L. Montgomery, An Introduction to the Theory of Numbers, 5th Ed., Wiley-India, 1991.

2 K. H. Rosen, Elementary Number Theory and its Applications, Pearson, 2015.

3 G. A. Jones and J. M. Jones, Elementary Number Theory, Springer-Verlag (1998).

Syllabus

Module 1. Mathematical Induction, The Binomial Theorem, Early Number theory, The Division Algorithm, The Greatest Common Divisor, The Euclidean Algorithm, The Diophantine Equation. (Chapter 1 and 2 of Text book 1).

Module 2. The Fundamental Theorem of Arithmetic, The Sieve of Eratosthenes, The Goldbach Conjecture. (Chapter 3 of Text book 1).

Module 3. Carl Friedrich Gauss, Basic Properties of Congruence, Binary and Decimal Representations of Integers, Linear Congruence and the Chinese Remainder Theorem. (Chapter 4 of Text book 1).

Module 4. Pierre de Fermat, Fermat's Little Theorem, Pesudoprimes, Wilson's Theorem, The Fermat-Kraitchik Factorization Method. (Chapter 5 of Text book 1).

Module 5. Euler's Criterion, The Legendre symbols and Its Properties, Quadratic Reciprocity, Quadratic Congruence with Composite Moduli. (Chapter 9 of Text book 1).

Cochin University of Science and Technology
Department of Mathematics

Mathematics – Core Papers

(Semester: 7 - 10)

Departmental Core

(Offered for students opting Mathematics as Major)

Semester VII
24-809-0701 - Linear Algebra

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the notion of vector spaces. Finite-dimensional vector spaces and maps between them preserving the structure are objects of study. The dual of a vector space also forms a major part of the study, especially with the study of the adjoint map. Studying the important multi-linear maps, like the Determinant map, form an important part of the course. Finally, the important primary decompositions of the vector space concerning a linear transformation is studied. This also helps to understand the extra symmetry in the representation of the matrices.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the notions of vector spaces, linear transformations, coordinates and the representation of transformation by matrices.	Understand
CO2	Know the dual space of a vector space and adjoint of a linear map that acts between the dual spaces.	Remember
CO3	Understand the important generalizations of linear maps to more than one variable especially the Determinant map and its important properties.	Understand
CO4	Comprehend ideas on the advanced topics like annihilating polynomials, simultaneous triangulation, diagonalization and direct sum decomposition.	Analyze
CO5	Know primary decompositions associated with subspaces or with respect to a given operator.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			

UNIT 1: Review of system of linear equations and their solution set, Vector spaces, Subspaces, Bases and dimensions, Coordinates, Summary of row equivalence, Linear Transformations, The Algebra of Linear transformations, Isomorphism, Representation of Transformations by matrices.

UNIT 2: Linear functionals, The double Dual, The Transpose of a Linear Transformation, Inner product spaces, Linear functionals and Adjoints. (Sections 3.1, 3.2, 3.3 and Sections 8.1, 8.2, 8.3 from Hoffman and Kunze)

UNIT 3: Bilinear forms, Symmetric forms: Orthogonality, The geometry associated to a positive form, Hermitian forms (Chapter 7 Sections 1, 2, 3, 4 from Artin), Determinants-Commutative rings, Determinant functions, Permutations and the Uniqueness of determinants. (Sections 5.1, 5.2, 5.3 from Hoffman and Kunze)

UNIT 4: Characteristic Values, Annihilating polynomials, Invariant subspaces, Simultaneous Triangulation, Simultaneous Diagonalization, Direct-Sum Decompositions, Invariant Direct

Sums, The Primary Decomposition Theorem. (Chapter 6 of Hoffman and Kunze)
UNIT 5: The Rational and Jordan Forms- Cyclic Subspaces and Annihilators, Cyclic Decompositions and the Rational Form, The Jordan Form. (Sections 7.1, 7.2, 7.3 from Hoffman and Kunze)
Text Books:

1. Kenneth Hoffman and Ray Kunze *Linear Algebra*, Second Edition, PHI (1975).

2. M. Artin, Algebra, Prentice-Hall, (1991)

References:-

1. M. Artin, *Algebra*, Prentice-Hall, (1991).

2. Serge Lang, *Introduction to Linear Algebra*, Second Editon, Springer (1997).

3. K.T Leung, *Linear Algebra and Geometry*, Hong Kong University Press, (1974).

4. S.Kumaresan, *Linear Algebra: A Geometric Approach*, Fist Edition PHI Learning (2009).

5. Sheldon Axler, *Linear Algebra Done Right*, Second Edition, Springer, (1997).

6. Richard Kaye and Robert Wilson, *Linear Algebra*, Oxford University Press, (1998).

Semester VII
24-809-0702 - Measure and Integration

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: One of the objectives of measure theory is to make platform for developing tools for a new method of integration of functions that are not Riemann integrable. Apart from studying the Lebesgue measure and integration, this course introduces the concept of general measure spaces and the integration in this setting also.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Comprehend Lebesgue measure and general measure spaces.	Understand
CO2	Evaluate integrals of measurable functions.	Evaluate
CO3	Understand the basics of Lp spaces.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3	1		

Pre-requisites: Familiarity with complex numbers and basic calculus, Geometric ideas of school level.
UNIT 1: The Axiom of Choice, Zorn's Lemma, Lebesgue Outer measure, Measurable sets and Lebesgue measure, Non measurable sets (Chapter 2 and relevant sections of Preliminaries of the text)
UNIT 2: Lebesgue measurable functions: Litlewood's Three Principles, The Riemann Integral, The Lebesgue Integral (Chapters 3 and 4 of the text, upto section 4.3)
UNIT 3: The General Lebesgue Integral, Continuity of Integration, Convergence in Measure, Characterizations of Riemann and Lebesgue integrability, Differentiation of monotone functions, Lebesgue's theorem, Functions of bounded variations: Jordan's Theorem (avoid proofs of Vitali Covering lemma and Lebesgue's theorem). (Section 4.4-4.5, 5.2-5.3 and 6.1-6.3 of the text)
UNIT 4: Differentiation of an integral, Absolute continuity, Convex Functions, The L^p spaces, Minkowski and Hölder inequalities, (Section 6.4-6.6 and 7.1-7.2 of the text)
UNIT 5: Completeness of L^p spaces, Approximation and Separability, The Riesz Representation for the Dual of L^p spaces (Section 7.3-7.4 and 8.1 of the text)

Text Book: H L Royden, P. M. Fitzpatrick, Real Analysis, Fourth Edition (2009), PHI

References:-

1. I K Rana, An Introduction to Measure and Integration, Narosa Publishing Company.

2. P R Halmos, Measure Theory, GTM , Springer Verlag.

3. T.W. Gamelin, Complex Analysis, Springer.

4. R.G. Bartle, The elements of Integration (1966) John Wiley & Sons, Delhi,(2006)

5. K B. Athreya and S N Lahiri:,Measure theory, Hindustan Book Agency, New Delhi.

6. Thamban Nair, Measure and Integration: A First Course, CRC Press, 2019.

7. Terence Tao: An Introduction to Measure Theory,Graduate Studies in Mathematics,Vol 126 AMS.

8. S. Kesavan Measure and Integration, Hindustan Book Agency, Springer (TRIM 77).

Semester VII
24-809-0703 - Groups and Rings

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the basic algebraic structure Group, and studies various aspects of groups. It also covers another mathematical structure Rings and various types of rings.
Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the definition of a group, order of a finite group and order of an element.	Remember
CO2	Comprehend different types of subgroups such as normal subgroups, cyclic subgroups, and understand the structure of these subgroups.	Remember
CO3	Understand the concepts of permutation groups, factor groups and group homomorphisms.	Understand
CO4	Know basics of advanced topics such as Sylow's theorem and apply those results.	Understand
CO5	Understand other mathematical structures such as rings and various classes of rings, their sub structures like ideals, and their homomorphisms.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			

UNIT 1: Introduction to Groups: Basic Axioms and Examples, Dihedral Groups, Symmetric Groups, Matrix Groups, The Quaternion Group, Homomorphisms and Isomorphisms, Group Actions; Subgroups: Definitions and Examples, Centralizers and Normalizers, Stabilizers and Kernels. Subgroups: Cyclic groups, Groups generated by subsets of a Group, The Lattice of Subgroups of a Group.(Chapter 1 and Chapter 2 of Textbook)
UNIT 2: Quotient Groups and Homomorphisms: Quotient Groups, homomorphisms, Langange's Theorem, The Isomorphism Theorems, Composition Series and Holder Program, Transpositions and Alternating Group, Group Actions: Group actions and permutation representations, Cayley's Theorem. (Chapter 3 of Textbook sections 3.1-3.5 and Chapter 4 of Textbook sections 4.1, 4.2)
UNIT 3: Group Actions: Groups acting on themselves by conjugation-The Class Equation, Orbits, Counting Lemma, Automorphisms, Sylow Theorems, Applications of Sylow's theorems, Simplicity of A_n. (Chapter 4 of Textbook sections 4.3-4.6)
UNIT 4: Rings: Basic Definitions and Examples, Examples: Polynomial Rings, Matrix Rings, and Group Rings, Ring Homomorphisms an Quotient Rings, Properties of Ideals. (Chapter 7 of Textbook sections 7.1 - 7.4)
UNIT 5: Factorization in domains: Euclidean Domains, Principal Ideal Domains (P.I.D.s), Unique Factorization Domain (Chapter 8 of Textbook 1 sections 8.1, 8.2, 8.3)

Text Books:

1. Abstract Algebra - D.S. Dummit and R.M. Foote, 3rd Edition, Publisher: Wiley.

References:-

1. A First Course in Abstract Algebra - J.B. Fraleigh, 7th Edition, Publisher - Pearson
2. Algebra - M. Artin, Second Edition, Publisher - Pearson
3. Contemporary Abstract Algebra - J. A. Gallian, 4th Edition, Publisher - Narosa
4. Topics in Algebra - I.N. Herstein, Second Edition, Publisher - Wiley Student Edition.
5. Rings and Modules - C. Musili, Second revised edition, Narosa Publishing House.

Semester VII
24-809-0704 - Topology I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: Topology is essentially the study of surfaces in which normally non geometric properties are studied. This course introduces the basic concepts of topology and standard properties such as compactness connectedness, separation axioms.
Learning Outcomes: On completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know basic topological spaces	Remember
CO2	Understand topological properties	Understand
CO3	Understand the connection of topology with other branches of Mathematics	Understand
CO4	Apply topological properties to prove theorems.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			1
CO4	3			

Pre-requisites: Basic ideas of Set Theory, Basic concepts of Real Analysis and Metric Spaces.
UNIT 1: Topological Spaces: Logical warm up, Motivation for topology, Definition of topological spaces, examples, Bases and Sub bases, Subspaces. (Chapter 3 & 4 of Text 1)
UNIT 2: Basic Concepts: Closed sets and Closure, Neighbourhoods, Interior and Accumulation Points, Continuity and Related Concepts, Making functions continuous and Quotient Spaces (Chapter 5 of Text 1)
UNIT 3: Spaces with special properties: Smallness conditions on a space, Connectedness, Locally connectedness and paths. (Chapter 6 of Text 1)
UNIT 4: Separation axioms: Hierarchy of separation axioms, Compactness and separation axioms, Urysohn's characterization of normality, Tietze extension Theorem. (Chapter 7 of Text 1)
UNIT 5: Product and Coproducts: The Cartesian product of family of sets, product topology, productive properties, Embedding Lemma, Embedding theorem and Urysohn's Metrization Theorem. (Relevant sections of Chapter 8 & 9 of Text 1)

Text Book: K.D. Joshi: Introduction to General Topology (Revised Edn.), New Age International (P) Ltd., New Delhi, Revised printing in 1984.

References:-

1. G.F. Simmons: Introduction to Topology and Modern Analysis; McGraw-Hill International Student Edn.; 1963

2. J. Dugundji: Topology; Prentice Hall of India; 1975

3. J. R. Munkers; Topology (Second Edition) PHI, 2009.

4. M. Gemignani: Elementary Topology; Addison Wesley Pub Co Reading Mass; 1971

5. M.A. Armstrong: Basic Topology; Springer- Verlag New York; 1983
6. M.G. Murdeshwar: General Topology (2nd Edn.); Wiley Eastern Ltd; 1990
7. S. Willard: General Topology; Addison Wesley Pub Co., Reading Mass; 1976
8. John Gilbert Hocking and Gail S. Young, Topology (Revised Edition), Dover Publications, (1988).

Semester VIII
24-809-0801 - Field Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the advanced topics in Group theory. It also covers other mathematical structures Modules and Fields.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the advanced concepts of group theory such as direct products and semi-direct products.	Remember
CO2	Understand the groups of small orders so as to classify them using the advanced concepts such as semi-direct products and direct products.	Understand
CO3	Comprehend the concept of algebraic structures called modules and various types of modules.	Remember
CO4	Apply the ideas of Field theory for problem-solving.	Apply
CO5	Apply group-theoretic information to deduce results about fields and polynomials.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3	1		
CO5	3			

UNIT 1: Direct product of Abelian Groups: Direct products, Fundamental theorem of finitely generated abelian groups, Groups of small order, Recognizing direct products, p-groups, Nilpotent groups and Solvable groups. (Chapter 5 of Textbook 1 sections 5.1-5.4, Chapter 6 of Textbook 1 section 6.1)
UNIT 2: Polynomial Rings: Definitions and Basic Properties, Polynomial Rings over Fields I, Polynomial Rings that are Unique Factorization Domains, Irreducibility Criteria, Polynomial Rings over Fields II. (Chapter 9 of TextBook 1 sections 9.1, 9.2,9.3 , 9.4, 9.5)
UNIT 3: Fields: Basic Theory of Field Extensions, Algebraic Extensions, Classical Straightedge and compass constructions, Splitting Fields and Algebraic Closures. (Chapter 13 son Textbook 1 sections 13.1, 13.2, 13.3, 13.4)
UNIT 4: Fields: Separable and Inseparable Extensions, Cyclotomic Polynomials and Extensions, Galois theory: Basic Definitions, The Fundamental Theorem of Galois Theory, Finite Fields. (Chapter 13 sections 13.5, 13.6 of Textbook 1 and Chapter 14 sections 14.1, 14.2, 14.3 of Textbook 1)
UNIT 5: Galois theory: Composite Extensions and Simple Extensions, Cyclotomic Extensions and Abelian Extensions over Q, Galois groups of polynomials, Solvable and Radical Extensions: Insolubility of the Quintic. (Chapter 14 sections 14.4-14.7 of Textbook 1)
Text Books:

1. Abstract Algebra - D.S. Dummit and R.M. Foote, 3rd Edition, Publisher: Wiley.

References:-

1. A First Course in Abstract Algebra - J.B. Fraleigh, 7th Edition, Publisher - Pearson
2. Algebra - M. Artin, Second Edition, Publisher - Pearson
3. Contemporary Abstract Algebra - J. A. Gallian, 4th Edition, Publisher - Narosa Publishing
4. Topics in Algebra - I.N. Herstein, Second Edition, Publisher - Wiley Student Edition
5. Rings and Modules - C. Musili, Second revised edition, Narosa Publishing House.
6. Galois Theory - J. Rotman, Second Edition, Springer International Edition.

Semester VIII
24-809-0802 - Functional Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This is the first part of the series of 2 courses taught in the second and third semester on Functional Analysis. In the first part, we cover important structures used in analysis like Banach spaces, Hilbert spaces and operators acting on them. The foundation results are discussed in this part.
Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the concepts of Banach spaces, Hilbert spaces and their examples.	Understand
CO2	Understand the action of operators in Normed spaces and Innerproduct spaces.	Understand
CO3	Know the basics of duals and transpose of a space.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Pre-requisites:

1. A first course in linear algebra
2. Basic real analysis and topology

UNIT 1: Review of Linear Spaces and Linear Maps, Metric Spaces and Continuous Functions, Lebesgue Measure and integration on R. (Chapter I, Section 2, 3, and 4; excluding the proofs of 2.1, 2.3, 3.4, 3.5, 3.9 and 3.10).
UNIT 2: Normed Spaces, Continuity of Linear Maps, Hahn-Banach Theorems (Chapter II, Section 5, 6, 7; upto Theorem 7.11).
UNIT 3: Banach Spaces., Uniform Boundedness Principle, Closed Graph and Open Mapping Theorem, Bounded Inverse Theorem. (Chapter III, Section 8, 9 upto Theorem 9.4, Section 10).
UNIT 4: Bounded Inverse Theorem, Inner Product Spaces, Orthonormal Sets. (Chapter III: Section 11, Chapter VI: Section 21, 22)
UNIT 5: Duals and Transpose. Duals of $L^p([a,b])$ and $C([a,b])$. (Chapter IV, Section 13, 14; upto Theorem 14.5).
Text Book: Balmohan V. Limaye, *Functional Analysis*, Revised Second Edition, New Age International Publishers, 1996 (Reprint 2013)

References:-

1. Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).
2. Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).
3. E. Kreyzig, Introduction to Function Analysis with Applications, Addison – Wesley.

4. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).
5. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).
6. Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork (1975).
7. Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi(2009).
8. G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.
9. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd (2001).

Semester VIII
24-809-0809 - Complex Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of complex functions which will be followed by the Classical theory of analytic functions. This will involve some of the classical theorems in the subject such as Cauchy's integral formula and its' general forms.
Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand Conformal mapping and Linear transformations.	Understand
CO2	Know Analytic functions and some classical results in this regard.	Remember
CO3	Apply basic results like residue theorems to evaluate complex integrals.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	2		

Pre-requisites: Familiarity with complex numbers and basic calculus, Geometric ideas of school level.
UNIT 1: The field of complex numbers, The complex plane, Polar representations and roots of complex numbers, Lines and half planes in complex plane, The extended plane and its spherical representations, Power series, Analytic functions and Analytic functions as mapping and Mobius transformations. [Chapter - I (Sections - 2,3,4,5,6), Chapter - III (Sections - 1,2,3)]
UNIT 2: Riemann-Stieltjes integrals, Power series representation of analytic functions, Zeros of an analytic function and The index of a closed curve [Chapter - IV (Sections - 1,2,3,4)].
UNIT 3: Cauchy's Theorem and Integral Formula, The homotopic version of Cauchy's Theorem and simple connectivity, Counting zeros; the Open Mapping Theorem and Goursat's Theorem [Chapter - IV (Sections - 5,6,7,8)].
UNIT 4: Classification of singularities, Residues and The Argument Principle [Chapter - V (Sections - 1,2,3)].
UNIT 5: The Maximum Principle, Schwarz's Lemma, Convex functions and Hadamard's Three Circles Theorem and Phragmen-Lindelof Theorem [Chapter - VI (Sections - 1,2,3,4)].

Text Book: J.B. Conway, Functions of One Complex Variable (2^{nd} Edition), Springer 1973.

References:-

1. L.V. Ahlfors, Complex Analysis (Third Edition) Mc-Graw Hill International (1979)

2. Milnor, Dynamics in One Complex Variable (3rd ed.), Princeton U. Press.

3. T.W. Gamelin, Complex Analysis, Springer

4. H. A. Priestley: Introduction to Complex Analysis, Oxford University Press.

5. J.H. Mathews and R.W. Howell: Complex Analysis for Mathematics and Engineering, Jones & Bartlett Learning.

Semester VIII
24-809-0804 - Functions of Several Variables and Geometry

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective:

- In the first module, the students will be introduced to inner product theory and multivariable functions in Euclidean spaces and the notion of differentiation in several variables.
- In the second module we go deeper in the theory of multivariable differentiation and see their application in the inverse function theorem, implicit function theorem and the maxima-minima theory.
- In the third module we apply the notions of multi-variable differentiation and associated local properties to regular curves and surfaces.
- Differentiable manifolds are introduced in the fourth module. Examples and differentiable maps between differentiable manifolds are studied along with their associated tangent planes are studied.
- In the fifth module the notions of geometry are introduced. The Riemannian metric structure on a differentiable manifold is introduced for conceptual clarity. The fundamental forms on regular surfaces are also introduced.

Learning Outcomes: After completion of this course, the students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand continuity and differentiability of functions of several variables and their applications.	Understand
CO2	Apply these concepts to regular curves and surfaces in Euclidean spaces.	Apply
CO3	Know the idea of tangent planes to regular surfaces and differentiable manifolds with examples.	Remember
CO4	Understand the concept of orientation of vector fields on such manifolds.	Understand
CO5	Know the Riemannian structure on a differentiable manifold which makes the study of geometry on regular surfaces in R^3 more clear conceptually.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			1

Pre-requisites:

1. Basic real analysis and Linear Algebra

UNIT 1: Norm and inner product, subsets of Euclidean spaces, functions and continuity, (Differentiation in several variables) Basic definitions, basic theorems, partial derivatives, derivatives. (Sections 1.11, 8.1, 8.2, 8.4, 8.6, 8.7, 8.8, 8.10, 8.11, 8.12, 8.13, 8.15, 8.16, 8.18, 8.19, 8.20, 8.21, 8.23 of textbook 1)
UNIT 2: Inverse functions, Implicit functions (Sections 13.2, 13.3, 13.4 of textbook 2, Sections 9.6, 9.7 of textbook 1), Maximima, Minima and Saddle points, Second order Taylor formula for scalar fields, nature of a stationary point determined by the eigenvalues of the Hessian matrix, Second-derivative test for extrema of functions of two variables. (Sections 9.9, 9.10, 9.11, 9.12 of Textbook 1)
UNIT 3: Regular curves, The local theory of curves parametrised by arc length, The local canonical form, Regular surfaces, Change of parameters, The tangent plane.(Sections 1.3, 1.5, 1.6, 2.2, 2.3, 2.4 of textbook 3)
UNIT 4: Introduction to differentiable manifolds, tangent space of differentiable manifolds, Immersions and embeddings, other examples, Orientation, vector fields, brackets, topology of manifolds. (Chapter 0 of textbook 4)
UNIT 5: Introduction to Riemannian metrics, Riemannian metrics (Chapter 1 of textbook 4), The first fundamental form (Area), Orientation of Surfaces. (Sections 2.5, 2.6 of textbook 3)

Text Books:-

1. Michael Spivak: *Calculus on Manifolds A modern approach to classical theorems of advanced calculus*, Addison-Wesley Publishing house, 1965.

2. Manfredo P. Do Carmo: *Differential geometry of curves and surfaces*, Dover Publications, Second edition, 2016.

3. Manfredo P. Do Carmo: *Riemannian Geometry*, Birkhauser, 1993.

References:-

1. Andrew Pressley: Elementary Differential Geometry, Springer, 2000.

2. Theodore Shifrin: Differential Geometry: A first course in curves and surfaces, 2016.

Semester IX
24-809-0901 - Operator Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This is the second part of the series of 2 courses taught in the second and third semester on Functional Analysis. In the second part, we focus on compact operators on Banach spaces, Hilbert spaces and their spectral properties.
Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the basic notions of spectral theory.	Remember
CO2	Understand the idea of compact self-adjoint operators.	Understand
CO3	Analyse spectrum of operators	Analyze
CO4	Evaluate problems using operators for approximate solutions.	Evaluate

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3	1		

Pre-requisites:

1. A first course in functional analysis
2. Basic real analysis and topology

UNIT 1: Spectrum of a Bounded Operator, Weak and Weak* Convergence, Reflexivity. (Chapter III, Section 12, Chapter IV, Section 15, upto Theorem 15.5, Chapter IV: Section 16 excluding the proof of Theorem 16.5).
UNIT 2: Compact Linear Maps, Spectrum of a Compact Linear Map. (Chapter V, Section 17, 18).
UNIT 3: Fredholm Alternative, Approximate Solutions, Normal, Unitary and Self-Adjoint Operators (Chapter V, Section 19, 20, upto Theorem 20.4, Chapter VII: Section 26).
UNIT 4: Approximation and Optimization, Projection and Riesz Representation Theorems. Bounded Operators and Adjoints. (Chapter VI: Section 23, 24, 25)
UNIT 5: Spectrum and Numerical Range, Compact Self-adjoint Operators, Sturm-Liouville Problems. (Chapter VII, Section 28, Appendix C).

Text Book: Balmohan V. Limaye, *Functional Analysis*, Revised Second Edition, New Age International Publishers, 1996 (Reprint 2013)

References:-

1. Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).
2. Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).
3. E. Kreyzig, Introduction to Function Analysis with Applications, Addison – Wesley.

4. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).

5. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).

6. Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork (1975).

7. Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi(2009).

8. G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.

9. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd (2001).

Semester IX
24-809-0902 - Ordinary Differential Equations & Integral Equations

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of Ordinary differential equations. Course aims to build an understanding of the classical models in terms of ordinary differential equations and pave the foundations for the study of Integral equations.

Learning Outcomes: At the end of teh course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Compare solutions of first order differential equations using Separation and Comparison theorems.	Analyze
CO2	Know basics of Legendre Polynomials and Bessel polynomials along with their important properties.	Remember
CO3	Analyse critical points and stability of linear systems.	Analyze
CO4	Understand integral equations and method of successive approximations.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	2	1	
CO4	3	2		

UNIT 1: Oscillations and the Sturm Separation Theorem, The Sturm Comparison Theorem, Series solutions of First order equations, Second order Linear Equations, Gauss's Hyper Geometric Equation. (Chapter 4, Section 24, 25. Chapter 5, sections 27, 28, 29, 30, 31.)
UNIT 2: Legendre Polynomials, Properties of Legendre Polynomials, Bessel Polynomials, Properties of Bessel Polynomials. (Chapter 8, sections 44, 45, 46, 47.)
UNIT 3: Systems, Nonlinear equations: Autonomous systems, The Phase Plane and its Phenomena, Types of Critical points. Stability, Critical points and Stability for Linear Systems. (Review Chapter 10, Chapter 11, Sections 58, 59,60)
UNIT 4: Method of successive approximations, Picard's Theorem, Integral Equations with separable kernels, Fredholm Integral Equations, Method of successive approximations. (Chapter 13, sections 68, 69 of text 1, Chapter 2 and 3 of the text 2.)
UNIT 5: The Fredholm Method of Solution, Fredholm's Theorems, Applications to Ordinary Differential Equations. (Chapters 4, 5 of the text 2)
Text Books:

1. George F. Simmons, *Differential Equations with Applications and Historical Notes*, Tata McGraw-Hill, Third Editon 2003.

2. Ram P. Kanwal, *Linear Integral Equations*, Second Edition, Springer Science+Business Media, LLC, (1997).

References:-

1. Peter J. Collins, *Differential and Integral Equations*, Oxford University Press,(2006).

2. Carmen Chicone, *Ordinary Differential Equations with Applications*, Springer (2006).

3. Linear Integral Equations

4. Michael D. Greenberg, *Ordinary Differential Equations*, Wiley (2012).

5. Michael E. Taylor, *Introduction to Differential Equations*, AMS (2011).

6. Vladimir I. Arnol'd, *Ordinary Differential Equations*, Springer (1992).

7. Earl A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications, New york, (1961).

Semester X
24-809-1001 - Partial Differential Equations and Variational Calculus

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with simple models of Partial differential equations which will be followed by the analytic and algebraic study of PDEs. This will involve some of the classical models in the subject: diffusion equations and wave equations. Towards the end of the course students will get an idea of variational calculus.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the concepts of classical models of diffusion and wave phenomena	Remember
CO2	Understand the terminology and concepts of partial differential equations	Understand
CO3	Apply solution techniques of PDE's for problem-solving.	Apply
CO4	Know basics of variational problems and solution techniques.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	1		
CO3	3	2	1	
CO4	3	1		

UNIT 1: Classification of First-Order Equations, Construction of a First-Order Equation, Geometrical Interpretation of a First-Order Equation, Method of Characteristics and General Solutions, Canonical Forms of First-Order Linear Equations, Method of Separation of Variables (Chapter 2 of Text 1).
UNIT 2: The Vibrating String, The Vibrating Membrane, Waves in an Elastic Medium, Conduction of Heat in Solids, Second-Order Equations in Two Independent Variables, Canonical Forms, Equations with Constant Coefficients, The Cauchy Problem, Charpit's method. (Chapter 3, sections 3.2-3.5, Chapter 4 of Text 1, Sections 5.1-5.4.).
UNIT 3: Eigenvalue Problems and Special Functions, Sturm–Liouville Systems, Eigenfunction Expansions, Completeness and Parseval's Equality, Bessel's Equation and Bessel's Function (Sections 8.1-8.6 of the Text 1).
UNIT 4: Variation and its properties, Euler equation, Functionals involving higher order derivatives, Functionals involving partial derivatives, Variational problems with movable boundaries. (Chapter 1, 2 of text 2).
UNIT 5: Sufficiency condition for an extremum, Variational problems with constrained extrema, isoperimetric problems, Direct methods, Euler's method of finite differences, Ritz method. (Chapter 3, 4, 5 of text 2).

Text 1. Tyn Myint-U, Lokenath Debnath *Linear Partial Differential Equations for scientists and Engineers*, Fourth Edition, Birkhauser (2007).

Text 2. Lev D. Elsgolc, *Calculus of Variations*, Dover publications, Inc. (2007.)

References:-

1. Walter A. Strauss, *Partial Differential Equations an Introduction*, John Wiley, (1992).

2. Ravi P. Agarwal, Donal O'Regan, *Ordinary and Partial Differential Equations With Special Functions, Fourier Series, and Boundary Value Problems*, Springer-Verlag (2009).

3. Fritz. John, *Partial Differential Equations*, Fourth Edition, Springer (2009).

4. G. Evans, I. Blackedge and P.Yardley, *Analytic Methods for Partial Differential Equations*, Springer (1999).

5. Ian N. Sneddon, *Elements of Partial Differential Equations*, McGraw Hill (1983).

Semester X
24-809-1002 - Probability Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the introduction to probability theory following different probability distributions. The connection between probability theory and measures are also discussed in this course. This will involve some of the classical theorems in the subject such as central limit theorem and law of large numbers.
Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know fundamental concepts of probability theory and classical results.	Remember
CO2	Apply basic ideas of probability theory for problem solving.	Apply
CO3	Comprehend probability spaces and different kinds of convergence associated with it.	Evaluate

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	2	2	1
CO3	3			

Pre-requisites:

1. A first course in measure theory.
2. Basic real analysis and topology.

UNIT 1: Recalling Probability: Sample Space, events and probability, Independence and conditioning, Discrete random variables, The branching process, Borel's strong law of large numbers (Chapter 1)
UNIT 2: Integration: Measurability and measure, The Lebesgue integral, The other big theorems (Chapter 2)
UNIT 3: Probability and Expectation: From integral to expectation, Gaussian vectors, Conditional expectation (Chapter 3)
UNIT 4: Convergences Almost-sure convergences, Two other types of convergence, Zero-one laws (Chapter 4, section 4.1-4.3)
UNIT 5: Convergence continued: Convergence in distribution and in variation, Central Limit Theorem, The hierarchy of convergences (Chapter 4, section 4.4-4.6)

Text. Pierre Bremaud, Probability Theory and Stochastic Processes, Springer 2020.

References:-

1. S.R. Athreya, V.S. Sunder: Measure and Probability, University Press (India) Pvt. Ltd. (2008).
2. Sidney I Resnick: A Probability Path, Birkhauser 2005 Edition
3. A.K. Basu: Probability Theory, Prentice Hall, India, 2002.
4. W. Feller: An Introduction to Probability Theory and Its Applications.

Cochin University of Science and Technology
Department of Mathematics

Mathematics – Elective Papers

(Semester: 7, 8, 9 and 10)

Departmental / Interdepartmental Elective

(Offered for students opting Mathematics as Major. Students from other disciplines can also opt.)

Semester VII
24-809-0705 - Real Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the structure of Real Numbers. This course is planned to introduce the notions Metric Spaces, Continuity, Uniform continuity, Differentiation, Riemann-Steiltjes integration, Fundamental theorem of Calculus, Convergence of sequence of functions, Uniform convergence, Stone-Weierstrass Theorem and Power series.

Learning Outcomes: After the completion of this course, the student should able to

No.	Course Outcome	Cognitive level
CO1	Know basics of calculus and other important notions on the set of real numbers	Remember
CO2	Understand in detail metric spaces, continuity, uniform continuity and differentiation	Understand
CO3	Apply the ideas of Riemann-Steiltjes integration and fundamental theorem of calculus for problem-solving	Apply
CO4	Analyse the convergence of sequence of functions	Analyze
CO5	Know uniform convergence, Stone-Weierstrass Theorem and basics of power series	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	1		
CO4	3			
CO5	3			

UNIT 1: Metric Spaces; Definition and examples, open and closed sets in metric space, compactness, Connectedness, Continuity, Uniform continuity, discontinuity.(Chapter 2 and 4)
UNIT 2: Derivative: Derivatives and continuity, L' Hospital Rules, Mean-Value theorem, Derivatives of vector-valued functions.(Chapter 5)
UNIT 3: The Riemann-Steiltjes integrals, Fundamental theorem of Calculus, Differentiation under integral signs, integration under vector valued function, rectifiable curves. (Chapter 6)
UNIT 4: Sequences and series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. (Chapter 7, sections upto 7.18)
UNIT 5: Equicontinuous families of functions, Stone-Weierstrass Theorem, Power series. (Chapter 7; sections upto 7.18-7.33, Chapter 8; sections up to 8.5)

Text Book: Walter Rudin, Principles of Mathematical analysis, 3rd edition, McGraw-Hill Higher Education (1976).

References:-

1. Terence Tao, Analysis I and II, Third Edition, Springer 2016.

2. N.L Carothers, Real Analysis, Wiley 2000.

3. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).

4. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).

5. A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).

6. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).

7. S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)

8. K. A. Ross, Elementary Analysis; Theory of Calculus, Springer-Verlag,(2013).

Semester IX
24-809-0905 : Topics in Applied Mathematics
(Inter-departmental elective. Not for students opting Mathematics)

Number of credits: 3
Number of hours per week: 4 hrs
Total No. of Hours: 72 hours

Objective: To learn important Mathematical Tools applicable in Science and Technology.

Learning Outcomes: After the completion of this course, the student should able to

No.	Course Outcome	Cognitive level
CO1	Understand the necessary mathematical tools that are used in science and technology	Understand
CO2	Understand popular transforms of Laplace and Fourier and their applications to various fields	Understand
CO3	Comprehend common mathematical models like vibating string, Heat conduction and their solutions using transforms.	Apply
CO4	Know necessary machinery in complex function theory	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3		1	
CO2	3	2		
CO3	3	2		
CO4	3	1		

UNIT 1: Second order Linear ODEs, Homogeneous Linear ODEs of Second Order, Homogeneous Linear ODEs with Constant Coefficients, Euler-Cauchy Equations.
UNIT 2: Laplace Transform, Linearity, First Shifting Theorem (s-Shifting), Transforms of Derivatives and Integrals ODEs, Unit Step Function (Heaviside Function), Second Shifting Theorem (t-Shifting)
UNIT 3: Fourier Series, Arbitrary Period, Even and Odd Functions, Half-Range Expansions, Forced Oscillations, Fourier Integral, Fourier Cosine and Sine Transforms, Fourier Transform.
UNIT 4: Basic Concepts of PDEs, Modeling: Vibrating String, Wave Equation, Modeling: Heat Flow from a Body in Space, Heat Equation
UNIT 5: Complex Numbers: Preliminary requirements, limits, Continuity, Cauchy-Reimann equations, Complex Integration, Line Integral in the complex plane, Cauchy's Integral Theorem, Cauchy's Integral formula, Derivatives of Analytic functions, Laurent Series, Singularities and zeros, Residue Integration method, Residue Integration of real Integrals.

Text Book: Advanced Engineering Mathematics, Erwin Kreyszig, 10^{th} edition, JOHN WILEY & SONS, INC.2011. (Chapter 2, Section 2.1-2.3, and 2.5, Chapter 6, Section 6.1-6.4, Chapter 11, Section 11.1-11.3, 11.7,11.8, Chapter 12, Section 12.1-12.6, Chapter 14, Section 14.1-14.4, Chapter 16, Section 16.1-16.4.)

References:-

1. Advanced Engineering Mathematics, C.Ray Wylie, Louis. C. Barrett, 6th edition, McGraw Hill Publishing, 1998.

2. Advanced Engineering Mathematics, K.A Stroud, 5th edition, Palgrave Macmillain, 2003.

3. Advanced Engineering Mathematics, Michael Greenberg, 2nd edition, Prentice Hall, 1998.

4. Advanced Engineering Mathematics, Dennis. G.Zill, Warren S.Wright, 4th edition, 2011.

Semester IX or X
24-809-0906/ 24-809-1006 : Advanced Linear Algebra

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of linear algebra, which will be followed by the factorisation and triangulation theorems. This will also discuss canonical forms and eigenvalue inequalities and inclusions for hermitian matrices. Some important results in linear algebra are discussed here which are not done in the core courses on this subject. This will benefit students wants to pursue research in the areas like Functional Analysis, Spectral theory, Stochastic models, Numerical linear algebra, etc.
Learning Outcomes: After the completion of this course, the students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand the advanced concepts of linear algebra and matrix analysis.	Understand
CO2	Know the skills to deal with advanced techniques in estimating eigenvalues, singular values, etc.	Apply
CO3	Know basics of Eigenvalue perturbation theorems	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Pre-requisites:

1. A basic course in linear algebra and matrix theory.
2. Normed spaces and basic analysis.

UNIT 1: Review of Linear Algebra: Eigenvalues, Algebraic and geometric multiplicity, Special types of matrices, Change of basis, etc.
UNIT 2: Unitary matrices and QR factorization, Unitary similarity, Triangulation theorems and consequences, Singular Value Decomposition (SVD).
UNIT 3: Jordan canonical form and its consequences, minimal polynomial, Triangular factorization.
UNIT 4: Hermitian matrices, Eigenvalue inequalities, diagonalization.
UNIT 5: Matrix norms, Condition numbers, Gersgorin discs, Eigenvalue perturbation theorems.

Text Book: Roger A Horn, Charles R Johnson, Matrix Analysis, Second Edn., Cambridge University Press, 2013.

References:-

1. M. Artin, Algebra, Prentice-Hall, (1991).
2. Serge Lang, Introduction to Linear Algebra, Second Edition, Springer (1997).
3. K.T Leung, Linear Algebra and Geometry, Hong Kong University Press, (1974).
4. Kenneth Hoff man and Ray Kunze Linear Algebra, Second Edition, PHI (1975)
5. Sheldon Axler, Linear Algebra Done Right, Second Edition, Springer, (1997).

Semester IX or X
24-809-0907/ 24-809-1007: Discrete Framelets

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: Course is aimed to introduce the basic tools for applications using Discrete Framelets. Students will get knowlege in analysing signals and images using finite filters. This course will pave the necessary foundations to study numerical solutions of partial differential equations and some insights into computer aided geometric design.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the subject in a signal processing perspective with the help of finite filters	Understand
CO2	Know filter-bank theory for signal analysis	Apply
CO3	Understand the multilevel framelet decomposition of signals in bounded intervals.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	2	1	
CO3	3	2	1	

UNIT 1: Discrete Framelet Transform, Perfect reconstruction of discrete framelet transforms, One-Level Standard Discrete Framelet Transforms, Perfect Reconstruction of Discrete Framelet Transforms, Some Examples of Wavelet or Framelet Filter Banks. (Section 1.1 of text.)
UNIT 2: Sparsity of Discrete Framelet transforms, Convolution and Transition Operators on Polynomial Spaces, Subdivision Operator on Polynomial Spaces, Linear-Phase Moments and Symmetry Property of Filters, An Example. (Section 1.2 of text.)
UNIT 3: Multilevel Discrete Framelet Transforms and Stability, Multilevel Discrete Framelet Transforms, Stability of Multilevel Discrete Framelet Transforms, Discrete Affine Systems in $\ell^2(\mathbb{Z})$, Nonstationary and Undecimated Discrete Framelet Transforms (Section 1.3 of text.)
UNIT 4: Oblique extension principle, OEP-Based Tight Framelet Filter Banks, OEP-Based Filter Banks with One Pair of High-Pass Filters, OEP-Based Multilevel Discrete Framelet Transforms. (Section 1.4 of text.)
UNIT 5: Discrete Framelet Transforms for signals on bounded Intervals, Boundary Effect in a Standard Discrete Framelet Transform, Discrete Framelet Transforms Using Periodic Extension, Discrete Framelet Transforms Using Symmetric Extension, Symmetric Extension for Filter Banks Without Symmetry, Discrete Framelet Transforms Implemented in the Frequency Domain. (Section 1.5 and 1.6 of text.)

Text. Bin Han, Framelets and Wavelets Algorithms, Analysis and Applications, Birkhauser 2017.

References:-

1. Ole Christensen, Frames and Bases An Introductory Course, Birkhauser, 2008.

2. Ole Christensen, Frames and Riesz Bases, Birkhauser, 2008.

3. Christopher Heil, A Basis Theory Primer, Citeseer, 1998.

4. Yves Meyer, Wavelets and Operators, CUP, England, 1992.

5. Ingrid Daubechies, Ten Lectures on Wavelets, SIAM, Philadelphia, 1992.

Semester IX or X
24-809-0908/ 24-809-1008 : Harmonic Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of Measure theory. This course is planned to introduce the basics of Topolgical groups and measure and Intergration on Locally compact groups.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know basics of Modular functions and convolutions.	Remember
CO2	Understand the fundamental ideas of representations	Understand
CO3	Comprehend the formulation of Measure and integration on Locally compact groups and representations of Compact groups.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			1

UNIT 1: Topological groups, Haar Measure, Modular Functions, Convolutions (Sections 2.1, 2.2, 2.3, 2.4, 2.5)
UNIT 2: Homogeneous spaces, Unitary Representations, Representation of a group and its group algebra (Sections 2.6, 2.7, 2.8, 3.1, 3.2)
UNIT 3: Functions of positive type, The Dual group, The Fourier transform, The Pontrjagin Duality theorem (Sections 3.3, 3.4, 4.1, 4.2, 4.3)
UNIT 4: Representations of Locally Compact Abelian Groups, Closed ideals, Spectral synthesis, Bohr Compactification(Sections 4.4, 4.5, 4.6, 4.7, 4.8)
UNIT 5: Representations of Compact Groups, The Peter-Weyl Theorem, Fourier Analysis on Compact Groups. (Sections 5.1, 5.2, 5.3, 5.4, 5.5)
Text Book: Folland, G.B., *A Course in Abstract Harmonic Analysis*, CRC Press, (1995).

References:-

1. Hewitt, E and Ross K., *Abstract Harmonic Analysis* Vol.1 Springer (1979).

2. Gaal, S.A., *Linear Analysis and Representation Theory*, Dover (2010).

3. Asim O. Barut and Ryszard Raczka, *Theory of Group Representations*, second revised edition, Polish scientific publishers (1980).

4. Groenchenig, K., *Foundations of time frequency analysis*, Birkhauser Boston (2001).

Semester IX or X
24-809-0909/ 24-809-1009 : Integral Transforms

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with Fourier Transforms in detail. This course is planned to introduce the basics of Integral Transforms and its applications in various fields.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the basic integral transforms	Remember
CO2	Understand fundamental theorems in integral transforms	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			

UNIT 1: Integral Transforms, The Fourier Integral Formulas, Fourier Transforms of generalised functions, Basic Properties of Fourier Transforms, Z-transforms (Sections 1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5 and Chapter 12)
UNIT 2: Poisson's Summation formula, The Shannon Sampling Theorem, Gibbs Phenomenon, Heisenbergs' Uncertainty Principle, Applications of Fourier Transform to ODE, Laplace Transforms and their basic properties. (Sections 2.6, 2.7, 2.8, 2.9, 2.10, 3.1, 3.2, 3.3, 3.4)
UNIT 3: Convolution Theorem and the properties of convolution, Differentiation and Integration of Laplace transforms, The Inverse Laplace Transforms, Tauberian theorems and Watson's Lemma, Applications of Laplace transforms, Evaluation of Definite Integrals, Applications of Joint Laplace and Fourier Transform. (Sections 3.5, 3.6, 3.7, 3.8, 3.9, 4.1, 4.2, 4.3, 4.6, 4.8)
UNIT 4: Finite Fourier Sine and Cosine transforms, Basic properties and Applications, Finite Lapace Transforms, Tauberian Theorems. (Chapter 10, 11)
UNIT 5: Hilbert Transform and its basic properties, Hilbert transform in the complex plane, applications of Hilbert Transform, Asymptotic expansion of One sided Hilbert Transform. (Sections 9.1, 9.2, 9.3, 9.4, 9.5, 9.6)
Text Book: Lokenath Debnath, Dambaru Bhatta *Integral Transforms and their Applications*, second edition, Taylor and Francis, (2007).

References:-

1. Frederick W. King, *Hilbert Transforms*, CRC (2009).

2. Larry C. Andrews, Bhimsen K. Shivmaoggi *Integral Transforms for Engineers*, (1999).

3. Ian N. Sneddon, *The Fourier Transforms*, Dover Publishers (1995).

4. Joel L.Schiff, *Laplace Transforms: Theory and Applications*, second revised edition, Springer (1980).

5. B.Davies, *The Integral Transforms and their applications*, Springer-Verlag (1978).

6. Ian N. Sneddon, *The Use of Integral Transforms*, McGraw-Hill (1972).

Semester IX or X
24-809-0910/ 24-809-1010 : Functions of Several Variables

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the structure of $\mathbb{R}^n$. This course is planned to introduce the Differential calculus on the finite dimensional Euclidean Space and Integration on $\mathbb{R}^n$.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know different kinds of derivatives especially directional derivative	Remember
CO2	Understand extremum problems of various kinds	Understand
CO3	Know multiple Riemann integrals and criteria for their existence	Remember
CO4	Comprehend basic theorems regarding Lebesgue integrals	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	2		
CO3	3			
CO4	3			

UNIT 1: Multivariable Differential Calculus, Directional Derivatives and continuity, Total Derivative, The Jacobian matrix, Matrix form of the chain rule, Taylor formula for functions from $\mathbb{R}^n$ to $\mathbb{R}$ (Chapter 12)
UNIT 2: Implicit Functions and Extremum problems, functions with nonzero Jacobian determinant, Inverse function theorem, Implicit funtion theorem, Extrema of real-valued functions of several variables, Extremum problems with side conditions(Chapter 13)
UNIT 3: Multiple Riemann Integrals, The measure of a bounded interval in $\mathbb{R}^n$, Riemann Integral of a bounded funtion on a compact interval in $\mathbb{R}^n$, Lebesgue criterion for the existence of a multiple Riemann integral. (Chapter 14, Sections 14.1, 14.2, 14.3, 14.4, 14.5)
UNIT 4: Jordan Measurable sets in $\mathbb{R}^n$, Multiple Integration over Jordan-measurable sets, Step functions and their integrals, Fubini's reduction thorem for the double integral of a step function. (Chapter 14, 15 Sections 14.6, 14.7, 14.8, 14.9, 14.10, 15.1,15.2,15.3,15.4, 15.5)
UNIT 5: Multiple Lebesgue Integrals, Fubini's reduction theorem for double integrals ,Tonelli-Hobson test for integrability The transformation formula for multiple integrals(Chapter 15, Sections 15.6, 15.7, 15.7, 15.8, 15.9, 15.10, 15.11, 15.12, 15.13)
Text Book: Tom M. Apostol, *Mathematical Analysis*, Second Edition, Addison-Wesley 1974.

References:-

1. Serge Lang, *Calculus Of Several Variables*, Addison-Wesley Publications, (1973).

2. C.H. Edwards Jr.,*Advanced Calculus of Several Variables*, Academic Press New York, (1973).

3. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, New York (1986).

4. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, New York (1991).

5. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London, (1996).

6. K. A. Ross, Elementary Analysis; Theory of Calculus, Springer-Verlag, 2013.

Semester IX or X
24-809-0911/ 24-809-1011 : Advanced Spectral Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of Spectral Theory of Linear Operators in Normed Spaces. The idea of this course is to cover various classifications of spectrum and finally present the spectral theorem for bounded self-adjoint operators. Applications to quantum mechanics is also done.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the use of complex analysis in spectral theory.	Understand
CO2	Know the spectral properties of operators with some properties.	Remember
CO3	Know spectral representation of some important operators.	Remember
CO4	Analyse the unbounded linear operators in quantum mechanics	Analyze

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			1

Pre-requisites:

1. Functional Analysis, Basic Analysis.

2. Linear Algebra.

UNIT 1: Review of Spectral Theory of Linear Operators in Normed Spaces; Properties of Resolventa and Spectrum, Use of Complex Analysis in Spectral Theory. (Chapter 7)
UNIT 2: Spectral Properties of Bounded Self-adjoint Operators; Positive Operators, Spectral Family. (Chapter 9, Section 9.1 to 9.7)
UNIT 3: Spectral Theorem for Bounded Self-adjoint Operators, Properties of Spectral Family. (Chapter 9, Section 9.8 to 9.11)
UNIT 4: Unbounded Linear Operators in Hilbert Spaces; Spectral Representation of Unitary Operators, Spectral Representation of Self-Adjoint Operators (Unbounded). (Chapter 10)
UNIT 5: Unbounded Linear Operators in Quantum Mechanics. (Chapter 11)

Text Book: E. Kreyzig, Introduction to Functional Analysis with Applications, Addison – Wesley.

References:-

1. Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).

2. Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).

3. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).

4. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).

5. Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork, (1975).

6. Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi (2009).

7. G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.

8. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd. (2001).

Semester IX or X
24-809-0912/ 24-809-1012 : Banach Algebra and Spectral Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course introduces the notion of Banach Algebras. The theory of commutative Banach algebras are discussed in detail. Also, the spectral theory of bounded and unbounded operators on Hilbert spaces are discussed.

Learning Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know Banach algebras in detail	Remember
CO2	Understand the properties of commutative Banach algebras and their substructures.	Understand
CO3	Understand the spectral properties of bounded and unbounded operators with examples.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: A first course in Functional Analysis, Complex Analysis, Linear Algebra, Topology and Measure Theory is needed. The core courses taught in the first three semesters of the M.Sc. program will do the purpose.
UNIT 1: Banach Algebras: Introduction, Complex homomorphisms, Basic properties of Spectra, Symbolic Calculus, Invariant subspace theorem. (Chapter 10 of Text Book)
UNIT 2: Commutative Banach Algebras: Ideals and homomorphisms, Gelfand Transforms, Involutions, Positive functionals. (Chapter 11 of Text Book)
UNIT 3: Bounded Operators on a Hilbert Space: A commutativity theorem, Resolutions of the identity, The spectral theorem, Positive operators, An ergodic theorem. (Chapter 12 of Text Book)
UNIT 4: Unbounded Operators: Symmetric operators, The Cayley transform, Resolutions of the identity. (Chapter 13 of Text Book)
UNIT 5: Unbounded Operators (Contd.): The Spectral Theorem, Semigroup of Operators. (Chapter 13 of Text Book)

Text Book: Rudin, Walter. Functional Analysis. Second Edition. International Series in Pure and Applied Mathematics. McGraw-Hill, Inc., New York, 1991.

References:-

1. Takesaki, M. Theory of Operator Algebras I. Reprint of the first (1979) edition. Encyclopaedia of Mathematical Sciences, 124. Operator Algebras and Non-commutative Geometry, 5. Springer- Verlag, Berlin, 2002.

2. Arveson, William. An Invitation to C*-algebras. Graduate Texts in Mathematics, No. 39. Springer-Verlag, New York-Heidelberg, 1976.

3. Douglas, Ronald G. Banach Algebras Techniques in Operator Theory. Second Edition. Graduate Texts in Mathematics, 179. Springer-Verlag, New York, 1998.

Semester IX or X
24-809-0913/ 24-809-1013 : Number Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of theory of numbers which will be followed by the divisibility and prime. This will involve some of the classical theory in the subject such as congruences, the Chinese remainder theorem, quadratic reciprocity law, Arithmetic functions and diophantine equations.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know results concerning divisibility, primes and congruences	Remember
CO2	Apply the Chinese remainder theorem to solve congruence problems.	Apply
CO3	Understand quadratic reciprocity law, Arithmetic functions and diophantine equations in depth.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3			
CO3	3			1

UNIT 1: Introduction to Numbers, Divisibility, Primes, [Chapter - 1 (Sections - 1.1,1.2,1.3)]
UNIT 2: Congruences, Solutions to congruences, The Chinese remainder theorem. [Chapter - 2 (Sections - 2.1,2.2,2.3)]
UNIT 3: Quadratic residues, Quadratic reciprocity, The Jacobi symbol. [Chapter - 3 (Sections - 3.1,3.2,3.3)]
UNIT 4: Greatest integer function, Arithmetic functions, The Mobius inversion formula. [Chapter - 4 (Sections 4.1, 4.2, 4.3)]
UNIT 5: The equation $ax + by = c$, Simultaneous equations, Pythagorean triangles, Assorted examples. [Chapter - 5 (Sections 5.1,5.2,5.3,5.4)]

Text Book: I. Niven, H.S. Zuckerman and H.L. Montgomery, An Introduction to the Theory of Numbers, 4th Ed., Wiley, New York, (1980).

References:-

1. W.W. Adams and L.J. Goldstein, Introduction to the Theory of Numbers, 3rd ed., Wiley Eastern, (1972).

2. A. Baker, A Concise Introduction to the Theory of Numbers, Cambridge University Press, Cambridge, (1984).

3. K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, 2nd ed., Springer-Verlag, Berlin, (1990).

4. T.M. Apostol, An Introduction to Analytic Number Theory, Springer-Verlag, (1976).

Semester IX or X
24-809-0914/ 24-809-1014 : Representation Theory of Finite Groups

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: To introduce the facinating theory of representations to the learner. Group representation theory will be discussed in detail through FG- Modules. To discuss the irreducible representations which are the building blocks of representations in detail. Chacter of a representation is a beautiful idea which is playing a vital role in the study of representations, here we discuss the character table of a group in detrail and construct the character table which will in fact replace the group itself.

Learning Outcome: After completion of teh course, the student must be able to

No.	**Course Outcome**	**Cognitive level**
CO1	Understand in detail the idea of group representations such as permutation representation and linear representations.	Understand
CO2	Know basic theorems and concepts concerning representations.	Remember
CO3	Create the character table of some interesting class of groups.	Create

CO - PSO Mapping Table:

CO/PSO	**PSO1**	**PSO2**	**PSO3**	**PSO4**
CO1	3			
CO2	3			
CO3	3			1

UNIT 1: Vector spaces, Modules, FG- modules, Group representations, Group algebras and homomorphisms. (Sections 1 to 7 of the text.)
UNIT 2: Maschke's theorem, Schur's lemma, Irreducibility (Sections 8 to 11 of the text.)
UNIT 3: Conjugacy classes, Character, Irreducibility, Inner product, Character table, Normal subgroups and lifted characters. (Sections 12 to 17 of the text.)
UNIT 4: Elementary charactertables, Tensor products, Restriction to subgroup, Induced modules and characters. (Sections 18 to 21 of the text.)
UNIT 5: Properties of character tables. Permutation chracters. (Sections 24 and 29 of the text.)

Text Book: Gordon James and Martin Liebeck, Representation and Characters of Groups, Cambridge University Press, Second Edition, 2001.

References:-

1. Willim Fulton, Joe Harries, Representation theory, A first course, 191 Springer Verlag, ISBN 81-8128-134-9.

2. David S Dummit, Richard M. Foot, Abstract Algebra , Third edition, John Wiley & Sons, Inc. 2004.

3. Walter Ledermann, Introduction to group characters, Second edition, Cambridge University Press, 2008. ISBN 978-0-521-33781-6.

Semester IX or X
24-809-0915/ 24-809-1015 : Algebraic Topology

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: At the end of the course the students will have the necessary introduction to the subject of Algebraic topology. The algebraic notions of the fundamental group of a space and that of homology and even cohomology theories is covered in the course. All the important topological constructions and concepts conducive for the algebraic study are also studied with enough examples.

Learning Outcomes: At the completion of the course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand necessary topological concepts and constructions like attaching spaces, suspension, excision, homotopy and deformation retraction among others.	Understand
CO2	Know the fundamental group and classification of covering spaces.	Remember
CO3	Comprehend homology and cohomology theories, which will serve as an important application of their course in module theory	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

UNIT 1: Homotopy and homotopy type, Cell complexes, Operations on spaces, Two criteria for homotopy equivalence, the homotopy extension property. (Chapter 0 of Hatcher)
UNIT 2: Applications of Van Kampen's theorem, Covering spaces, lifting properties, Universal cover and classification of covering spaces, Deck transformations and properly discontinuous actions. (chapter 1 of Hatcher)
UNIT 3: Delta-complexes and Simplicial homology, Singular homology, Homotopy Invariance, Exact sequences and excision, Equivalence of simplicial and singular homology. (Chapter 2 of Hatcher)
UNIT 4: Cellular homology (with special emphasis on CW-complexes), Mayer-Vietoris sequences, Homology with coefficients, the formal viewpoint of homology theories (briefly) (Chapter 2 of Hatcher)
UNIT 5: The definition of cohomology groups, The Universal Coefficient theorem, computation of cohomology of spaces, Relative groups and the long exact sequence of a pair of spaces (X, A), Cup product and the Cohomology ring structure, Kunneth formula for product of spaces, Poincare duality. (Chapter 3 of Hatcher)

Text Book: Algebraic Topology, Allen Hatcher.

References:-

1. Lecture notes in Algebraic Topology, James F. Davis, Paul Kirk.

Semester IX or X
24-809-0916/ 24-809-1016 : Differential Geometry

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: The course is aimed to introduce the popular tools to perform a study of geometry with the help of calculus on an n-dimensional surface. Develop the notion of curvature of parametric surfaces with the idea of, vector fields along a parametrized curve on the surface. Towards the end of the course, students will get all the necessary foundations to study Riemannian Geometry.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the concepts of vector fields, tangent space, surfaces and its orientations.	Understand
CO2	Comprehend the spherical image of surfaces, geodesics, Weingarten map, and curvature of surfaces.	Analyze
CO3	Understand local equivalence of surfaces and parametrized surfaces.	Understand
CO4	Understand in depth, the ideas of rigid motions, congruence and isometries.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			

Pre-requisites: Linear Algebra, Multivariate Calculus, and Differential Equations.
UNIT 1: Graphs and level sets, Vector fields, Tangent spaces, Surfaces, Vector Fields on Surfaces; Orientation, Gauss map.
UNIT 2: Geodesics, Parallel Transport, Weingarten Map, Curvature of Plane Curves.
UNIT 3: Arc lengths, Line integrals, Curvature of surfaces
UNIT 4: Parametrized surfaces, Local equivalence of surfaces and parametrized surfaces.
UNIT 5: Differentiable manifolds, Introduction, Tangent space, Immersions and embeddings; examples, Other Examples of manifolds, Orientation, Vector fields, brackets, Topology of manifolds. (Chapter 0 of the text 2)

Texts:

1. J.A. Thorpe: Elementary Topics in Differential Geometry, Springer-Verlag [Chapters 1 -12, 14, 15, 22, 23]

2. Manfredo Perdigao do Carmo, Riemannian Geometry, Birkhauser 1993.

References:-

1. L. M. Woodward, J. Bolton, A First Course in Differential Geometry: Surfaces in Euclidean Space, Cambridge university press, 2019.

2. Edouard Goursat, A Course in Mathematical Analysis, Vol. 1, Forgotten Books, 2012.

3. Andrew Pressley, Elementary Differential Geometry, second edition, Springer 2010.

4. Dirk J. Struik, Lectures on Classical Differential Geometry, Dover publications Inc. 1988.

5. Kreyszig, Introduction to Differential Geometry and Reimannian Geometry, University of Toronto Press, 1968.

Semester IX or X
24-809-0917/ 24-809-1017 : Algebraic Graph Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course aims to introduce students to the interconnection between Algebra and Graph Theory.

Outcome: After completing the course, the student will be able to

No.	Course Outcome	Cognitive level
CO1	Know transitivity in graphs.	Remember
CO2	Understand important matrices related to graphs.	Understand
CO3	Apply graph theoretic techniques in algebra and vice-versa.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: Basic knowledge of Algebra and Graph Theory

Text books:

1 C. Godsil and G. Royle: Algebraic Graph Theory, Springer, 2001.

Reference books:

1 R. B. Bapat: Graphs and Matrices, Springer, 2014.

2 N. Biggs: Algebraic Graph Theory (2nd edn.), Cambridge, 1993.

Syllabus

Module 1: Review of Graphs: Graphs, Subgraphs, Automorphisms, Homomorphisms, Circulant Graphs, Johnson Graphs, Line Graphs, Planar Graphs
(Section 1.1 - 1.8 of Text Book 1).

Module 2: Review of Groups: Permutation Groups, Counting, Asymmetric Graphs, Orbits on Paths, Primitivity, Connectivity
(Section 2.1 - 2.6 of Text Book 1).

Module 3: Transitive Graphs: Vertex transitive graphs, Edge transitive graphs, Edge connectivity, Vertex connectivity, Matchings
(Section 3.1 - 3.5 of Text Book 1).

Module 4: Matrix Theory: Adjacency matrix, Incidence matrix, Incidence matrix of oriented graphs, Symmetric matrices
(Section 8.1 - 8.4 of Text Book 1).

Module 5: Strongly Regular Graphs: Parameters, Eigen values, Some characterizations, Latin square graphs
(Section 26, 27 of Text Book 1).

Semester IX or X
24-809-0918/ 24-809-1018 : Wavelets

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the structure of $\mathbb{C}^n$. This course is planned to introduce the Wavelets as an extension to the idea of Fourier's method in Linear algebraic perpsective.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know Multi-resolution analysis and its applications	Remember
CO2	Apply ideas of wavelets in the space of periodic functions, non-periodic functions square integrable functions on the real line.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	1		1

UNIT 1: The Discrete Fourier Transform, Translation-Invariant Linear Transformations, First Stage Construction of Wavelets on $\mathbb{Z}_N$ (Chapter 2, Chapter 3, Sections 2.1, 2.2, 3.1)
UNIT 2: Construction of Wavelets on $\mathbb{Z}_N$: Iteration step, Examples and Applications, $l^2(\mathbb{Z})$ (Chapter 3, Sections 3.2, 3.3, Chapter 4, Section 4.1)
UNIT 3: Complete Orthonormal Sets in Hilbert Spaces, $L^2([-\pi, \pi))$ and Fourier Series, The Fourier Transform and Convolution on $l^2(\mathbb{Z})$ (Chapter 4, Sections 4.2, 4.3, 4.4, 4.5)
UNIT 4: First-Stage Wavelets on $\mathbb{Z}$, The Iteration step for Wavelets on $\mathbb{Z}$, Implementation and Examples. (Chapter 4, Sections 4.6, 4.7, Chapter 5, Section 5.1,)
UNIT 5: $L^2(\mathbb{R})$ and approximate Identities, The Fourier Transform on $\mathbb{R}$, Multiresolution Analysis and Wavelets, Construction of MRA (Chapter 5, Sections 5.2, 5.3, 5.4)

Text Book: Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer-Verlag New York, (1999).

References:

1. Charles K. Chui, *An Introduction to Wavelets*, Academic (1992).

2. Ingrid Daubechies, *Ten Lectures on Wavelets*, SIAM, (1992).

3. K.R Unni, *Wavelets, Frames and Wavelet Bases in L^P Lecture notes*, Bhopal (1997).

4. Stephane Mallat, *A Wavelet Tour Of Signal Processing*, Academic Press (1999).

5. Don Hong, Jianzhong Wang, Robert Gardner, *Real Analysis with an Introduction to Wavelets*, Elsevier Academic Press (2005).

6. Yves Meyer, *Wavelets and Operators*, Cambridge University Press (1992).

7. John. J Beneditto, Michael W. Frazier *Wavelets-Mathematics and Applications*, CRC, (1994).

8. Eugenio Hernandez, Guido L. Weiss, *First course on wavelets*, CRC, (1996).

Semester IX or X
24-809-0919/ 24-809-1019 : Advanced Optimization Methods and Machine Learning

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course provides a detailed theoretical background on optimization in machine learning with a knowledge on python implementation.

Outcome: After completing the course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Create mathematical models in Machine learning	Create
CO2	Apply Deep Learning to develop algorithms for Python implementation.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	1
CO2	3	3	2	2

Text books:

1 Aggarwal, C. C., Aggarwal, L. F., & Lagerstrom-Fife. (2020). Linear algebra and optimization for machine learning (Vol. 156). Springer International Publishing.

Reference books:

1 Boyd, S., Boyd, S. P., & Vandenberghe, L. (2004). Convex optimization. Cambridge university press.

2 Noble, B., & Daniel, J. W. (1977). Applied linear algebra (Vol. 477). Englewood Cliffs, NJ: Prentice-Hall

3 Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. MIT press

4 Strang, G. (2019). Linear algebra and learning from data (Vol. 4). Cambridge: Wellesley-Cambridge Press.

5 Strang, G. (2016). Introduction to Linear Algebra (5th Edition). Wellesley Publishers (India), ISBN : 978-09802327-7-6.

Syllabus

Module 1: The Basics of Optimization, Convex Objective Functions, Properties of Optimization in Machine Learning, Computing Derivatives with respect to Vectors, Stochastic Gradient Descent, Use of Bias
(Sections 4.2, 4.3, 4.5, 4.6, 4.7.2, 4.7.3 of Text 1).

Module 2: Challenges in Gradient Based Optimization, Momentum Based Learning, Ada-Grad, Newton Method, Newton Method for Linear Regression, Newton Method- Challenges

and Solution
(Sections 5.2, 5.3.1, 5.3.2, 5.4, 5.5.1,5.6 of Text 1).

Module 3: Singular Value Decomposition- Introduction, SVD- A linear Algebra Perspective, SVD- An Optimization Perspective
(Sections 7.1 - 7.3 of Text 1)

Module 4: Applications of SVD- Dimensionality Reduction, Noise Removal, Moore- Penrose Pseudoinverse, Feature preprocessing, Outlier Detection, Feature Engineering, Numerical Algorithms for SVD, Python Implementation of SVD.
(Sections 7.4 - 7.5 of Text 1).

Module 5: Basics of Computational Graphs, Neural Networks as Directed Computational Graphs, Back-propagation in Neural Networks, Python Implementation of Feed Forward Back-Propagation Neural Network.
(Sections 11.1 - 11.2, 11.4 of Text 1).

Semester IX or X
24-809-0920/ 24-809-1020 : Commutative Algebra

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course is an advanced course in algebra. This course discusses the theory of commutative rings. These rings are of fundamental significance in Mathematics because of its applications to other topics such as algebraic number theory, algebraic geometry and many other advanced topics in mathematics.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the basic definitions concerning different classes of commutative rings, elements in commutative rings, and ideals in commutative rings.	Understand
CO2	Know the theory of modules, including the tensor product of modules and algebras, and localisation.	Remember
CO3	Know the theory of primary decomposition of ideals in a commutative rings.	Remember
CO4	Know the theory of integral dependance and integral extensions.	Remember
CO5	Know the definition and examples of Noetherian and Artinian rings.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			

UNIT 1: Rings and ideals: review of ideals in quotient rings; prime and maximal ideals, prime ideals under quotient, existence of maximal ideals; operations on ideals (sum, product, quotient and radical); Chinese Remainder theorem; nilradical and Jacobson radical; extension and contraction of ideals under ring homomorphisms; prime avoidance.
UNIT 2: Free modules; Projective Modules; Tensor Product of Modules and Algebras; Flat, Faithfully Flat and Finitely Presented Modules; Shanuels Lemma.
UNIT 3: Localisation and local rings, universal property of localisation, extended and contracted ideals and prime ideals under localisation, localisation and quotients, exactness property.
UNIT 4: Nagata's criterion for UFD and applications; equivalence of PID and one-dimensional UFD. Associated Primes and Primary Decomposition.
UNIT 5: Integral dependence, Going-up theorem, Integral Extensions: integral closure, Going-down theorem, Valuation rings, Chain Conditions. Definition and examples of Noetherian rings and Artinian rings.

Text Book: M.F. Atiyah and I.G. Macdonald, Introduction to commutative algebra, Addison-Wesley (1969).

References:

1. R.Y. Sharp: Steps in commutative algebra, LMS Student Texts (19), Cambridge Univ. Press (1995).

2. D. Eisenbud: Commutative algebra with a view toward algebraic geometry GTM (150), Springer-Verlag (1995).

3. H. Matsumura: Commutative ring theory, Cambridge Studies in Advanced Mathematics No. 8, Cambridge University Press (1980).

4. N.S. Gopalakrishnan: Commutative Algebra (Second Edition), Universities Press (2016).

5. Miles Reid: Undergraduate Commutative Algebra , Cambridge University Press (1995).

Semester IX or X
24-809-0921/ 24-809-1021 : Graph Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: The course introduce the concept of automorphism of simple graphs, graph operators, graph parameters and some interesting graph classes

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the basic concepts of graph theory	Understand
CO2	Know with clarity, graph operators, graph parameters and graph classes.	Remember
CO3	Create graph models of real-life problems.	Create
CO4	Apply graph theoretic tools to solve problems.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	2		3
CO4	3	2		2

UNIT 1: Basic Concepts, Degree of Vertices, Automorphism of a Simple Graph, Line Graphs, Operation on Graphs, Directed Graphs, Tournaments (Chapter 1: Sec. 1.1 - 1.12, Chapter 2: Sec. 2.1 - 2.3)
UNIT 2: Connectivity, Vertex Cuts and Edge Cuts, Connectivity and Edge Connectivity, Blocks, Trees, Definition, Characterization, Centers, Cayley's Formula, Applications (Chapter 3:Sec.3.1 – 3.4 (Theorem 3.4.3 omitted), Chapter 4: Sec. 4.1 - 4.5, 4.7)
UNIT 3: Independent sets, Vertex coverings, Edge Independent sets, Matchings, Factors, Matching in Bipartile Graphs, Eulerian Graphs, Hamiltonian Graphs, Hamilton Cycles in Line Graphs, 2-Factorable Graphs (Chapter 5: Sec. 5.1 - 5.5, Chapter 6: Sec. 6.1 - 6.3, 6.5 - 6.6)
UNIT 4: Graph Colorings, Critical Graphs, Brook's Theorem, Triangle Free Graphs, Edge Colorings, Chromatic Polynomials, Perfect Graphs, Triangulated Graphs, Interval Graphs (Chapter 7: Sec. 7.1 - 7.2, 7.3, 7.3.1, 7.5 – 7.6, 7.9, Chapter 9: Sec. 9.1 – 9.4)
UNIT 5: Planar and nonplanar graphs, Euler's Formula, Dual, Four Color Theorem and Five Color Theorem, Kuratowski's Theorem (without proof), Hamilton Plane graphs, Domination, Bounds, Independent Domination and Irredundance (Chapter8: Sec. 8.1 – 8.8, Chapter 10: Sec.10.1 – 10.3. 10.5)
Text Book: R. Balakrishnan, K. Ranganathan: A Text book of Graph Theory (Second Edition), Springer 2012.
References:-

1. D. B. West: Introduction to Graph Theory, 2nd ed. Prentice Hall, New Jersey (2011)

2. F. Harary: Graph Theory, Addison – Wesley Publishing Company, Inc. (1969).

3. M. C. Golumbic: Algorithmic Graph Theory and Perfect Graphs, Academic Press, New York (1980)

4. Teresa W. Haynes, S. T. Hedetneimi, P. J. Slater: Fundamentals of Domination in Graphs, Marcel Dekker, New York (1998)

Semester IX or X
24-809-0922/ 24-809-1022 : C^*-Algebra and Representation Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course aims to provide the fundamentals of C^*-algebras, Von Neumann algebras and their representation theory.

Outcome: After this course student will able to

No.	Course Outcome	Cognitive level
CO1	Comprehend recent research articles by own reading.	Analyze
CO2	Understand the basic ideas in the representation theory of C^*-algebras.	Understand
CO3	Analyse problems in representation theory of C^*-algebras to come up with solutions.	Analyze

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			1
CO2	3			
CO3	3	1		2

Text book:

1. Murphy, Gerard J. C^*-algebras and operator theory. Academic Press, Inc., Boston, MA, 1990.

Reference books:

1. Arveson, William. An invitation to C^*-algebras. Graduate Texts in Mathematics, No. 39. Springer-Verlag, New York-Heidelberg, 1976.
2. Sunder, V. S. Functional analysis. Spectral theory. Birkhäuser Advanced Texts: Basler Lehrbücher. [Birkhäuser Advanced Texts: Basel Textbooks] Birkhäuser Verlag, Basel, 1997.
3. Conway, John B. A course in functional analysis. Second edition. Graduate Texts in Mathematics, 96. Springer-Verlag, New York, 1990.
4. Davidson, Kenneth R. C^*-algebras by example. Fields Institute Monographs, 6. American Mathematical Society, Providence, RI, 1996.
5. Douglas, Ronald G. Banach algebra techniques in operator theory. Second edition. Graduate Texts in Mathematics, 179. Springer-Verlag, New York, 1998.

SYLLABUS

Module 1: C^*-Algebras and Hilbert Space Operators: C^*-Algebras, Positive Elements of C^*-Algebras, Operators and Sesquilinear Forms, Compact Hilbert Space Operators and The Spectral Theorem. (Chapter - 2 of Text Book - 1).

Module 2: Ideals and Positive Functionals: Ideals in C^*-Algebras, Hereditary C^*-Subalgebras , Positive Linear Functionals, The Gelfand-Naimark Representation and Toeplitz Operators. (Chapter - 3 of Text Book - 1).
Module 3: Von Neumann Algebras: The Double Commutant Theorem, The Weak and Ultraweak Topologies, The Kaplansky Density Theorem and Abelian Von Neumann Algebras. (Chapter - 4 of Text Book - 1).
Module 4: Representations of C^*-Algebras: Irreducible Representations and Pure States, The Transitivity Theorem, Left Ideals of C^*-Algebras, Primitive Ideals, Extensions and Restrictions of Representations, Liminal and Postliminal C^*-Algebras. (Chapter - 5 of Text Book - 1).
Module 5: Direct Limits and Tensor Products: Direct Limits of C^*-Algebras, Uniformly Hyperfinite Algebras, Tensor Products of C^*-Algebras, Minimality of the Spatial C^*-Norm and Nuclear C^*-Algebras and Short Exact Sequences. (Chapter - 6 of Text Book - 1).

Semester IX or X
24-809-0923/ 24-809-1023 : Reproducing Kernel Hilbert Spaces

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: Reproducing kernel Hilbert spaces have developed into an important tool in many areas, especially statistics and machine learning, and they play a valuable role in complex analysis, probability, group representation theory, and the theory of integral operators. This course aims to provide an introduction to the theory of reproducing kernel Hilbert spaces.

Outcome: After this course student will be able to

No.	Course Outcome	Cognitive level
CO1	Understand recent research articles in the theory of reproducing kernel Hilbert spaces.	Understand
CO2	Analyse problems in reproducing kernel Hilbert spaces and attempt solutions.	Analyze

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		2
CO2	3	1		2

Text book:

1. Paulsen, Vern I.; Raghupathi, Mrinal. An introduction to the theory of reproducing kernel Hilbert spaces. Cambridge Studies in Advanced Mathematics, 152. Cambridge University Press, Cambridge, 2016.

Reference books:

1. Jim Agler and John E. McCarthy, Pick interpolation and Hilbert function spaces, Graduate Studies in Mathematics, vol. 44, American Mathematical Society, Providence, Rhode Island, 2002.

2. N. Aronszajn, Theory of reproducing kernels, Trans. Amer. Math. Soc. 68 (1950), 337–404.

3. Ronald G. Douglas and Vern I. Paulsen, Hilbert modules over function algebras, Pitman Research Notes in Mathematics, vol. 217, Longman Scientific, 1989.

4. John B. Conway, A course in functional analysis, 2nd ed., Graduate Texts in Mathematics, vol. 96, Springer-Verlag, New York, 1990.

5. Donald Sarason, Complex function theory, American Mathematical Society, Providence, Rhode Island, 2007.

SYLLABUS

Module 1: Introduction: Definition of reproducing kernel Hilbert spaces (RKHS), Basic examples, Examples from analysis, Function theoretic examples. (Chapter - 1 of Text Book - 1).

Module 2: Fundamental results: Hilbert space structure, Characterization of reproducing kernels, The Reconstruction Problem. (Chapter - 2 of Text Book - 1).
Module 3: Interpolation and approximation: Interpolation in an RKHS, Strictly positive kernels, Best least squares approximants, The elements of H(K). (Chapter - 3 of Text Book - 1).
Module 4: Cholesky and Schur: Cholesky factorization, Schur products and the Schur decomposition, Tensor products of Hilbert spaces, Kernels arising from polynomials and power series. (Chapter - 4 of Text Book - 1).
Module 5: Operations on kernels: Complexification, Differences and sums, Finite-dimensional RKHSs, Pull-backs, restrictions and composition operators Composition operators, Products of kernels and tensor products of spaces, Push-outs of RKHS, Multipliers of a RKHS. (Chapter - 5 of Text Book - 1).

Semester IX or X
24-809-0924 / 24-809-1024 - Topology II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: With this course, the students will have a sound introductory knowledge of the topics in Algebraic topology. The first module is important to understand the topology of non-metric spaces. From second module onwards the student is gradually introduced to the important category of topological spaces and subsequently the algebraic machinery like simplicity homology and fundamental groups for their study. The course ends with a rigorous understanding of covering spaces.

Learning Outcomes: After completion of this course, the students will be able to

No.	Course Outcome	Cognitive level
CO1	Know nets and filters, the generalisation of sequences for topologies that are no more defined by a metric.	Remember
CO2	Understand the important geometric objects like complexes and Polyhedra and different identification spaces whose topology is studied.	Understand
CO3	Comprehend the definition of simplicial homology groups and apply them to compute the homology groups for certain important spaces.	Analyze
CO4	Understand the fundamental group and the Van Kampen theorem with examples.	Understand
CO5	Know covering spaces and their properties along with their classification.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			

UNIT 1: Nets and Filters: Definition and convergence of Nets, Topolgy and convergence of Nets, Filters and their convergence, Ultra filters (Tychnoff's theorem) (Relevant Sections from text 1)
UNIT 2: Geometric Complexes and Polyhedra: Introduction. Examples, Geometric Complexes and Polyhedra, Orientation of geometric complexes. **Simplicial Homology Groups:** Chains, cycles, Boundaries and homology groups, Examples of homology groups, The structure of homology groups, (Sections 1.1 to 1.4, Sections 2.1 to 2.3 from text 2)
UNIT 3: Simplicial Homology Groups (Contd.): The Euler Poincare's Theorem, Pseudomanifolds and the homology groups of S_n. **Simplicial Approximation:** Introduction, Simplicial approximation, Induced homomorphisms on the Homology groups, The Brouwer fixed point theorem and related results (Sections 2.4, 2.5, and Sections 3.1 to 3.4 from text 2)
UNIT 4: The Fundamental Group: Introduction, Homotopic Paths and the Fundamental Group, The Covering Homotopy Property for S1, Examples of Fundamental Groups. (Sections 4.1 to 4.4 from text 2)

UNIT 5: Covering Spaces: The Definition and Some Examples, Basic Properties of Covering Spaces, Classification of Covering Spaces, Universal Covering Spaces, Applications (Sections 5.1 to 5.5 of text 2)

Text Books:

1. K.D. Joshi: Introduction to General Topology (Revised Edn.),New Age International(P) Ltd., New Delhi, 1983.
2. F.H. Croom: Basic Concepts of Algebraic Topology, Springer, 1978

References:-

1. Allen Hatcher: Algebraic Topology, Cambridge University Press, 2002
2. C.T.C. Wall: A Geometric Introduction to Topology, Addison-Wesley Pub. Co. Reading Mass, 1972
3. Eilenberg S, Steenrod N.: Foundations of Algebraic Topology, Princeton Univ. Press, 1952.
4. J. R. Munkers: Elements Of Algebraic Topology, Perseus Books, Reading Mass, 1993, CRC, 2018.
5. J. R. Munkers: Topology (Second Edition) PHI, 2009.
6. Massey W.S.: Algebraic Topology : An Introduction, Springer Verlag NY, 1977
7. S.T. Hu: Homology Theory, Holden-Day, 1965

Semester IX or X
24-809-0925 or 24-809-1025 - Computational Mathematics Laboratory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of Numerical methods for differentiation and integration, and simple models of Partial differential equations. This course is planned to introduce the basics of mathematical documention setting using LaTeX. Introduction of programming using Python for solving Mathematical problems arising in various fields, that are covered in the Msc curriculum.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know how to prepare mathematical documnets in LATEX and Python.	Remember
CO2	Understand Python programming techniques.	Understand
CO3	Apply programming ideas to solve mathematical problems.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			1
CO2	3	2	1	
CO3	3	3	2	1

UNIT 1: Introduction to LaTeX Documentation setting, Standard document classes, Bibtex, standard environments, Macros, Table of contents, Bibliography styles, tables, Pstricks, Multiline math displays (Texts 1, 2)
UNIT 2: Introduction to programming with Python, Fundamentals, Data types, Functions, Pointers and string handling, Class, File handling, Programming Excercises from Linear Algebra, Number Theory, Numerical Approximations, Differential Equations. (Texts 3, 4, 5 , 6)
UNIT 3: Matplotlib, Numpy, and Scipy Exercises. (Texts 7, 3)
UNIT 4: Introduction to SageMath, Symbolic Calculus, Linear Algebra using SageMath, SageTex Package, Graphics, Combinatorics, Graph Theory (Text 8).
UNIT 5: Coding Theory using SageMath, Standard Rings and Fields (Text 8)

References:-

1. George *Grätzer*, *Math into LaTeX an Introduction to LaTeX and AMS-LaTeX*, Birkhauser Boston, (1996).

2. Donald. E. Knuth, *Computers & Type setting*, Addison-Wesley, (1986).

3. Hans Petter Langtangen, *A Primer on Scientific Programming with Python*, Third Edition, Springer (2012).

4. John M. Zelle, *Python Programming: An Introduction to Computer Science*, (2002).

5. Steven Lott, *Functional Python Programming*, Packt Publishing Ltd, (2015).

6. Jody. S. Ginther Start here: Python programming made simple for the Beginner.
7. John Hunter, Darren Dale, Eric Firing, Michael Droettboom, *Matplotlib Release 1.4.3*.
8. William Stein, *SAGE Reference Manual Release 2007.10.29*.

NB: A Lab Report type-setted in LaTeX by the student has to be submitted at the end of the semester.

DEPARTMENT OF PHYSICS

Scheme of Examinations and Syllabus for
the Five Year Integrated M.Sc. Major in Physics Degree Program

Approved by the Board of Studies in Physical and Mathematical Sciences
on 04 April 2024

(From 2024 admission onwards)

COCHIN UNIVERSITY OF
SCIENCE AND TECHNOLOGY

Cochin University of Science and Technology
Cochin - 682 022

Website: http://physics.cusat.ac.in

Scheme and Syllabus

Preamble

Physics is one of the fundamental scientific disciplines that deal with the universe's fundamental laws ranging from nano to cosmic scale. It is one of the oldest academic disciplines that emerged during the 17th century and continues to be a dynamic and evolving field. The knowledge of physics is indispensable to deepen our understanding of the world around us and for technological advancements that can shape our lives in profound ways. Scientifically advanced people are a prerequisite for a society to become a developed one in every aspect. Becoming a developed nation depends upon creating a critical mass of researchers who work on some of the forefront areas of scientific knowledge. Building quality manpower in fundamental subjects such as physics is essential for a society to create a strong foundation in science and technology and advance further.

The Department of Physics of Cochin University of Science and Technology envisions carrying out this mission by navigating students through quality advanced training in Physics and engaging in good scientific research through its Five-Year Integrated Masters' program with an option to exit after three years or four years with a Bachelors Degree. The Department is known for its collaborative and inclusive research environment that can help students develop a scientific temper, enabling them with skills useful for teaching, research, and industrial careers. The students are trained to develop excellent analytical and computational skills, which are imperative for success in any field in today's world.

Our Integrated M.Sc. syllabus is designed with the view that a student completing the course will have mastery of several specialized fields in physics. This is achieved through providing advanced elective topics in both theoretical and experimental physics. An entire semester devoted to Project work and seminars complements the advanced courses to give the students a firsthand experience in scientific research. The program is crafted to align with the latest trends and technological advancements in education. An increased focus on learning and using various computational tools in the curriculum ensures that the students are equipped for today's digital age.

Program Outcomes: Integrated M.Sc.

PO1: Demonstrate a comprehensive understanding of fundamental principles and concepts in basic sciences.

PO2: Analyze, evaluate, and synthesize complex scientific information and data using appropriate methods and techniques.

PO3: Apply scientific reasoning and critical thinking adeptly to recognize, assess, and resolve problems encountered in various scientific and technological contexts.

PO4: Utilize computing power, programming languages, and modern technologies proficiently to address scientific challenges, effectively integrating technological solutions into problem-solving processes.

PO5: Communicate scientific information effectively in written and verbal forms.

PO6: Achieve proficiency in using modern scientific tools and technologies for experimentation, data collection, analysis, and interpretation.

PO7: Adhere to ethical principles and practices in the conduct of scientific research and professional activities, and work collaboratively with others.

PO8: Engage in lifelong learning and professional development to enhance the knowledge and skills in basic sciences.

PO9: Embrace and practice constitutional values, including universal human values of truth, righteous conduct, peace, love, nonviolence, and scientific temper.

Program Specific Outcomes: Integrated M.Sc. Physics

PSO1: Attain mastery of advanced topics in Physics as per the aptitude of students.

PSO2: Acquire excellent analytical and computational skills.

PSO3: Equip the students to take up scientific research and teaching in academia/industry as a career and engage in lifelong learning.

PSO4: Gain hands-on experience on advanced scientific experiments and instrumentation.

PSO5: Acquire excellent abilities in various aspects of science communication.

Table of Contents

Scheme

Academic Pathways Offered by the Department of Physics

- **Physics Major:**
  - **3-year UG Program:** To earn a Physics Major in a 3-year UG Program, a student must complete a minimum of 68 credits in Physics, out of which 60 credits will be from mandatory (core) courses and 8 credits from electives.
  - **4-year UG Program (Honours):** To earn a Physics Major in a 4-year UG Program, a student must complete a minimum of 104 credits in Physics, out of which 92 credits will be from mandatory (core) courses, 8 credits from electives, and 4 credits from a project.
  - **4-year UG Program (Honours with Research):** To earn a Physics Major (With Research) in a 4-year UG Program, a student must complete a minimum of 104 credits in Physics, out of which 84 credits will be from mandatory (core) courses, 8 credits from electives, and 12 credits from a research project.
- **Physics Minor:**
  - **3-year UG Program:** To earn a Physics Minor in a 3-year UG Program, a student must complete a minimum of 27 credits in Physics, out of which 24 credits will be from mandatory (core) courses and 3 credits from an SEC elective.
  - **4-year UG Program:** To earn a Physics Minor in a 4-year UG Program, a student must complete a minimum of 35 credits in Physics, out of which 24 credits will be from mandatory (core) courses, 3 credits from an SEC elective, and 8 credits from electives.
- **Discipline Mention in Physics:**
  To earn a Discipline Mention in Physics in a 3-year or 4-year UG Program, a student must complete a minimum of 12 credits in Physics, out of which 8 credits will be from mandatory (core) courses and 4 credits from an elective course.

Semester – I

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-0101	Mechanics	PHY-Major-DSC, PHY-Minor-DSC, PHY-Disci-DSC.	100	3-0-2	50	50	100	4
24-807-0102	Electromagnetic Phenomena	PHY-Minor-DSC	100	4-0-0	50	50	100	4
24-807-0103	The World of Motion	PHY-MDC	100	3-0-0	50	50	100	3
Semester Credits	21 (AEC: 6, MDC: 3, Major Pathway: 4, Minor Pathway: 8) Cumulative Credits: 21							

L- Lecture, T - Tutorial, P - Practical Hours per week.

PHY-Major-DSC: Core course for students Majoring in Physics.

PHY-Minor-DSC: Core course for students Minoring in Physics.

PHY-Disci-DSC: Core course for students who choose discipline mention in Physics.

PHY-MDC: Multidisciplinary elective course offered to students whose Major or Minor pathways are different from Physics.

AEC: Ebility Enhancement Course (Languages).

MDC: Multidisciplinary Course.

Semester – II

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-0201	Waves and Optics	PHY-Major-DSC, PHY-Minor-DSC PHY-Disci-DSC.	100	3-0-2	50	50	100	4
24-807-0202	Thermodynamics	PHY-Minor-DSC	100	4-0-0	50	50	100	4
24-807-0203	Oscillations in Nature	PHY-MDC	100	3-0-0	50	50	100	3
Semester Credits	21 (AEC: 6, MDC: 3, Major Pathway: 4, Minor Pathway: 8) Cumulative Credits: 42							

Semester – III

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-0301	Basic Mathematical Physics	PHY-Major-DSC, PHY-Minor-DSC, PHY-Disci-DSE.	200	3-0-2	50	50	100	4
24-807-0302	Introductory Quantum Physics	PHY-Minor-DSC, PHY-Disci-DSE	200	4-0-0	50	50	100	4
24-807-0303	Quantitative Techniques in Physics	PHY-MDC	200	3-0-0	50	50	100	3
Semester Credits	21 (VAC: 6, MDC: 3, Major Pathway: 4, Minor Pathway: 8) Cumulative Credits: 63							

PHY-Disci-DSE: Elective course offered to students who choose discipline mention in Physics.

VAC: Value Added Course.

Semester – IV

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-0401	Classical Mechanics and Relativity	PHY-Major-DSC	200	4-1-0	50	50	100	4
24-807-0402	Electricity and Magnetism - I	PHY-Major-DSC	200	4-1-0	50	50	100	4
24-807-0403	Thermal Physics	PHY-Major-DSC	200	4-1-0	50	50	100	4
24-807-0404	Science Communication	PHY-SEC, PHY-Minor-DSE.	200	2-1-2	100	–	100	3
24-807-0405	Physics Lab - I	PHY-Major-DSC	200	0-0-8	100	–	100	4
Semester Credits	22 (VAC: 3, SEC:3, Major pathway: 16) Cumulative Credits: 85							

PHY-Minor-DSE : Elective course offered to students Minoring in Physics.

SEC: Skill Enhancement Course.

PHY-SEC: Skill Enhancement elective Course offered to all students. Check for any prerequisites in the detailed syllabus of the Course.

Semester – V

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-0501	Basic Electronics	PHY-Major-DSC	300	4-1-0	50	50	100	4
24-807-0502	Electricity and Magnetism - II	PHY-Major-DSC	300	4-1-0	50	50	100	4
24-807-0503	Introduction to Quantum Mechanics	PHY-Major-DSC	300	4-1-0	50	50	100	4
24-807-0504	Optics and Spectroscopy	PHY-Major-DSC, PHY-Minor-DSE	300	4-1-0	50	50	100	4
24-807-0505	Numerical and Computational Physics	PHY-Major-DSC	300	3-1-2	100	–	100	4
24-807-0506	Introduction to Instrumentation, Mechanical design and Workshop for Undergraduates	PHY-SEC, PHY-Minor-DSE	200	2-1-2	50	50	100	3
Semester Credits	23 (SEC:3, Major Pathway: 20) Cumulative Credits: 108							

Semester – VI

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-0601	Basic Solid State Physics	PHY-Major-DSC, PHY-Minor-DSE	300	4-1-0	50	50	100	4
24-807-0602	Basic Nuclear Physics and Applications	PHY-Major-DSC	300	4-1-0	50	50	100	4
24-807-06xx$^{@}$	Elective –	PHY-Major-DSE	300	4-1-0	50	50	100	4
24-807-06xx	Elective –	PHY-Major-DSE	300	4-1-0	50	50	100	4
24-807-0603	Physics Lab - II	PHY-Major-DSC	300	0-0-8	100	–	100	4
24-807-0604	Basic Skills in Vacuum Technology	PHY-SEC, PHY-Minor-DSE	200	2-1-2	50	50	100	3
Semester Credits	23 (SEC:3, Major Pathway: 20) Cumulative Credits: 131							

PHY-Major-DSE: Elective course offered to students Majoring in Physics.

xx$^{@}$ - Replace xx with numerical codes of the electives offered.

Internship

Students have to complete an internship of 2 credits (60 Hours of work) before the completion of Semester 6. Cumulative Credits: 133

Exit with 3-year UG Degree OR continue to 4th year.

Semester – VII

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-0701	Classical Mechanics	PHY-Major-DSC, PHY-Minor-DSE	400	4-1-0	50	50	100	4
24-807-0702	Electrodynamics	PHY-Major-DSC	400	4-1-0	50	50	100	4
24-807-0703	Quantum Mechanics	PHY-Major-DSC	400	4-1-0	50	50	100	4
24-807-0704	Advanced Experiments in Physics Lab-I	PHY-Major-DSC	400	0-0-8	100	–	100	4
24-807-0705	Student Seminar	PHY-Major-DSC	400	0-0-4	100	–	100	2
24-807-07xx	Elective –	PHY-Major-DSE, PHY-Minor-DSE	300, 400	4-1-0	50	50	100	4
Semester Credits	22 (Core: 22) Cumulative Credits: 155							

Semester –VIII

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-0801	Statistical Mechanics	PHY-Major-DSC	400	4-1-0	50	50	100	4
24-807-0802	Mathematical Physics	PHY-Major-DSC, PHY-Minor-DSE	400	4-1-0	50	50	100	4
24-807-0803	Project	PHY-Major-DSC	400	0-0-8	50	50	100	4
24-807-08xx	Elective –	PHY-Major-DSE, PHY-Minor-DSE	300, 400	4-1-0	50	50	100	4
24-807-0804	Advanced Experiments in Physics Lab-II	PHY-Major-DSC	400	0-0-8	100	–	100	4
24-807-0805	Student Seminar	PHY-Major-DSC	400	0-0-4	100	–	100	2
24-807-0806 *	Research Project	PHY-Major-DSC	400	0-5-14	100	100	200	12
Semester Credits	22 (Core: 22) Cumulative Credits: 177							

Exit with 4-year UG Degree OR continue to 5th year.

* **- Students pursuing 4-year UG Honours Degree (with research) shall do the Research Project (24-807-0806) instead of the Course 24-807-0802, Project (24-807-0803) and the Lab Course 24-807-0804.**

Semester – IX

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-0901	Nuclear and Particle Physics	PHY-Major-DSC	500	4-1-0	50	50	100	4
24-807-0902	Solid State Physics	PHY-Major-DSC	500	4-1-0	50	50	100	4
24-807-09xx	Elective –	PHY-Major-DSE	400, 500	4-1-0	50	50	100	4
24-807-09xx	Elective –	PHY-Major-DSE	400, 500	4-1-0	50	50	100	4
24-807-0903	Advanced Experiments in Physics Lab-III	PHY-Major-DSC	500	0-0-8	100	–	100	4
24-807-0904	Online Course**	PHY-Major-DSE	500	2-1-0	–	100	100	2
Semester Credits	22 (Core: 12, Elective: 10) Cumulative Credits: 199							

Semester – X

Course Code	Course Name	Course Type	Level	L-T-P	Marks Distribution			
					Cont. eval.	End Sem	Total	Credit
24-807-1001	Major Project@	PHY-Major-DSC	600	0-5-30	200	200	400	20
24-807-1002	Online Course **	PHY-Major-DSE	500	2-1-0	–	100	100	2
Semester Credits	22 (Core: 20, Elective: 2) Cumulative Credits: 221							

Total credit requirement at BSc Level: 133

Total credit requirement for the Program: 221

@Regarding the Major Project the following directions may be followed:

(a) The major project can be done within the department or in an external institution of National/International reputation. i.e. institutions like, IISc Bangalore, Various IIT's, IISERs, Central Universities, CSIR laboratories, NITs TIFR, Raman Research Institute, IIA, inter university centers like IUCAA, NPOL, ISRO, DRDO, IIEST, industrial organizations, etc and any other equivalent institution.

(b) If a student wants to do his/her project in an external institution he/she has to find the supervisor from a nationally/internationally reputed institution like as mentioned above. A consent letter from the external supervisor should be produced to the Department Head/Coordinator of the batch. The consent letter can be considered by the Department council/Department Head and approval can be given to the student to pursue the project with the supervisor concerned.

(c) An internal faculty in charge must be assigned by the Department Council/Department Head to each student who is doing the project in other institutions/departments.

(d) The internal faculty in charge will periodically monitor the progress of the students assigned to him/her.

(e) Continuous evaluation of the project must be done by the supervisor. In the case of projects done outside the department, this can be done either by the external supervisor alone or by internal faculty in charge (in cases where the external supervisor is not able produce an official evaluation statement) or by both the internal and external supervisors together.

(f) The department shall arrange a mid-term presentation for all students. This will form a part of the continuous evaluation.

(g) The students must submit a report at the end of the project, which is duly signed and recommended by the supervisor on or before the date stipulated by the Department. For projects done outside, the report must be duly signed by the external supervisor.

(h) The end semester evaluation in the form of a presentation followed by viva based on the project will be done in the Department by a committee appointed by the Department Council/Department Head.

** Online courses 24-807-0904 & 24-807-1002 can be selected by the students from a set of courses approved by the Department Council. The Department can recommend courses from reputed platforms like Swayam (UGC), Coursera, CUSAT - MOOC etc. The following guidelines will be applicable for the online course.

(a) A sub-committee appointed by the Department council can approve a set of courses that the students in the Department can take. This will be based on considerations such as the length of a course, the relevance of its content to the program, etc. The list of approved courses will be notified to the students before the beginning of the semester. The students are allowed to choose a course from this approved set only.

(b) The credit given by the department for such a course will be two regardless of its duration.

(c) Students may register and complete the online course at their convenience during the semester but before the submission of the final project report.

(d) At the end of the course, the student should produce a valid document regarding the successful completion of the Course and stating his/her marks/grades. The Department Council will ascertain that the document produced is satisfactory and recommend awarding two credits for the course along with the marks/grades obtained.

(e) If a student fails a course, he/she may take the same or another approved course after informing the council.

Syllabus

Semester I

24-807-0101: Mechanics

Credits: 4
Academic Level: 100
Hours per week: L - 3, T - 0, P - 2. Total Hours per semester: L - 45, P - 30

Course Objective

This course intends to develop the basics methods of analysing the mechanics of a system using the most fundamental rules of mechanics.

Course Outcome

CO	CO Statement	CL
CO1	Understand the Newtons laws of motion, the most fundamental rule of Mechanics	Understand
CO2	Enable the students to apply the Newtons law in order to analyse basic dynamics of physical systems	Apply
CO3	Acquire the capacity to use the energy conservation principle to understand the dynamics of a system	Apply
CO4	Familiarise the rules of understanding the different properties of the material world, like elasticity, surface tension, etc.	Understand
CO5	Perform simple experiments related to mechanics	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	0	1	2	1	0
CO2	1	2	1	0	0
CO3	0	2	1	0	0
CO4	0	1	1	0	0
CO5	0	0	2	3	0

Module I General introduction. Vectors: Notation, addition and multiplication of vectors, scalar and vector products, vector derivatives, velocity and acceleration, form invariance. Laws of motion: Equations of motion, motion under gravitational force, law of universal gravitation, motion under electric and magnetic forces, momentum conservation, friction. Frames of reference: inertial and non-inertial frames, absolute and relative velocity, Galilean and transformation.

Module II Conservation laws: Conservation of energy, conservative forces, power, Conservation of linear and angular momentum, center of mass frame, systems with variable mass. Harmonic oscillator: Example systems, importance in physics, kinetic and potential energy, damped harmonic oscillator, driven harmonic oscillator, superposition principle.

Module III Rigid-body dynamics: Equation of motion, angular momentum and kinetic energy, moments of inertia, rotations about fixed axes, moments and products of inertia: Principal axes and Euler's equations, Motion under inverse-square-law force: circular orbit, Kepler 's laws, Two-body problem.

Module IV Properties of matter: Elasticity, Stress, strain, elastic constants, Poisson's ratio relation connecting various elastic constants, Hydrodynamics, Streamline and turbulent flows-tubes of flow and equation of continuity energy possessed by a liquid- Bernoulli's theorem-Torricelli's theorem, Viscosity, critical velocity-flow of liquid through a capillary tube (Poiseulle's formula)-Stokes formula, Surface tension, surface energy.
Students will have to complete a set of experiments complementing the classroom teaching.

Text Books:

1. Mechanics, C. Kittel, W.D. Knight, M.A. Ruderman, C.A. Helmholz and B.J. Moyer, Berkeley Physics Course Vol 1, Tata McGraw-Hill Ltd (2008). (Chapters 1-9)

2. Elements of Properties of Matter, D. S. Mathur, S. Chand & Co (2008).

Reference Books:

1. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters 1-14).

2. Mechanics, L.D. Landau and I.M. Lifshitz, 3rd edition, Elseviar (2007).

3. The Feynman Lectures on Physics Vol I, Narosa Publications (2003). (Chapters 1-25).

24-807-0102: Electromagnetic Phenomena

Credits: 4
Academic Level: 100
Hours per week: L - 4, T - 0, P - 0. Total Hours per semester : L - 60

Course Objective:

The course is designed to introduce the topic of electomagnetic phenomena.

Course Outcomes:

CO	CO Statement	CL
CO1	Enable the students to calculate electric field due to a charge distibution	Apply
CO2	Calculate the electric potential due to various charge distributions	Apply
CO3	Calculate the magnetic effect of electric current and understand the concept of electromagnetic waves	Apply
CO4	Equip students to deal with possible applications of electricity and magnetism	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	0	0
CO2	3	1	2	0	0
CO3	3	1	2	0	0
CO4	3	1	2	0	0

Module I Electrostatics: Electric field, Electric field of – a ring of charge, charged line segment, uniformly charged disk, two oppositely charged infinite sheets. Gauss's law – Calculation of electric field using Gauss's law- charged sphere (conducting and insulating), oppositely charged parallel conducting plates. Chapters 21-23 University Physics, H.D. Young, Roger A Freedman

Module II Electric potential, calculation of electric potential of – charged conducting sphere, oppositely charged parallel plates, infinite line/charged conducting cylinder, ring of charge, line of charge. Chapters 21-23 University Physics, H.D. Young, Roger A Freedman

Module III Magnetic effect of electric current and EM waves: Magnetic field, magnetic field lines and magnetic flux, motion of charged particles in a magnetic field, applications of motion of charged particles, Magnetic force on current carrying conductor, Hall effect, Ampere's law and application, Faraday's law, Displacement current and Maxwell's equations. Chapters 27-29 University Physics, H.D. Young, Roger A Freedman

Module IV Mutual and self Inductance. Magnetic field energy, R-L, L-C, L-C-R circuits, Phasors and Alternating Currents, Resitance and reactance, Power in AC circuits, Resonance, Transformers, Maxwell's equations and electromagnetic waves, Plane em waves and the speed of light, Sinusoidal em waves, Standing em waves. Chapters 30-32 University Physics, H.D. Young, Roger A Freedman

Text Books:

1. University Physics, H.D. Young, Roger A Freedman
2. Conceptual Physics - Paul G Hewitt.

Reference Books:

1. Waves, F.S. Crawford Jr, Berkeley Physics Course Volume 3, Tata McGraw-Hill Ltd (2008)
2. Cohen B. L., Concepts of Nuclear Physics, Tata McGraw Hill (2008). Introduction to Electrodynamics, D. J. Griffiths, 4th Edition, Cambridge University Press (2017).
3. Electricity and Magnetism, Purcell, Berkeley Physics Course Volume 2, Tata McGraw-Hill Ltd (2008)
4. The Feynman lectures Volume I and Volume II, Narosa (2003)

24-807-0103: The World of Motion

Credits: 3
Academic Level: 100
Hours per week: L - 3, T - 0, P - 0. Total hours per semester: 45

Course Objective

The course intends to develop the basics methods of analysing the mechanics of a system using the most fundamental rules of mechanics.

Course Outcome

CO	CO Statement	CL
CO1	Understand the Newtons laws of motion, the most fundamental rule of Mechanics	Understand
CO2	Enable the students to apply the Newtons law in order to analyse basic dynamics of physical systems	Apply
CO3	Acquire the capacity to use the energy conservation principle to understand the dynamics of a system	Apply
CO4	Familiarise the rules of understanding the different properties of the material world, like elasticity, surface tension, etc.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	0	1	2	1	0
CO2	1	2	1	0	0
CO3	0	2	1	0	0
CO4	0	1	1	0	0

Module I General introduction. Vectors: Notation, addition and multiplication of vectors, scalar and vector products, vector derivatives, velocity and acceleration, form invariance. Laws of motion: Equations of motion, motion under gravitational force, law of universal gravitation, motion under electric and magnetic forces, momentum conservation, friction. Frames of reference: inertial and non-inertial frames, absolute and relative velocity, Galilean and transformation.

Module II Conservation laws: Conservation of energy, conservative forces, power, Conservation of linear and angular momentum, center of mass frame, systems with variable mass. Harmonic oscillator: Example systems, importance in physics, kinetic and potential energy, damped harmonic oscillator, driven harmonic oscillator, superposition principle.

Module III Rigid-body dynamics: Equation of motion, angular momentum and kinetic energy, moments of inertia, rotations about fixed axes, moments and products of inertia: Principal axes and Euler's equations, Motion under inverse-square-law force: circular orbit, Kepler 's laws, Two-body problem.

Module IV Properties of matter: Elasticity, Stress, strain, elastic constants, Poisson's ratio relation connecting various elastic constants, Hydrodynamics, Streamline and turbulent flows-tubes of flow and equation of continuity energy possessed by a liquid- Bernoulli's theorem-Torricelli's theorem, Viscosity, critical velocity-flow of liquid through a capillary tube (Poiseulle's formula)-Stokes formula, Surface tension, surface energy.

Text Books:

1. Mechanics, C. Kittel, W.D. Knight, M.A. Ruderman, C.A. Helmholz and B.J. Moyer, Berkeley Physics Course Vol 1, Tata McGraw-Hill Ltd (2008). (Chapters 1-9)

2. Elements of Properties of Matter, D. S. Mathur, S. Chand & Co (2008).

Reference Books:

1. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters 1-14).

2. Mechanics, L.D. Landau and I.M. Lifshitz, 3rd edition, Elseviar (2007).

3. The Feynman Lectures on Physics Vol I, Narosa Publications (2003). (Chapters 1-25).

Semester II

24-807-0201: Waves and Optics

Credits: 4
Academic Level: 100
Hours per week: L - 3, T - 0, P - 2. Total hours per semester : L - 45, P - 30

Course Objective

To impart the basic properties of oscillations and waves and to understand the interference and diffraction of light.

Course Outcome:

CO	CO Statement	CL
CO1	To introduce the mathematical foundation of Mechanics, complex numbers and oscillatory motion	Understand
CO2	To understand the concepts of oscillations of systems with more than one degree of freedom	Understand
CO3	To understand the concept of waves and comprehend the idea of interference of light	Understand
CO4	To understand diffraction of light	Understand
CO5	Perform simple experiments related to waves and optics	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	0	3	3	0	0
CO2	0	3	3	0	0
CO3	2	3	2	1	0
CO4	2	3	2	1	0
CO5	1	0	1	2	2

Module I Review of Mechanics- Complex Numbers- Free Oscillations- One degree of freedom-Stable equilibrium and Restoring Force- Free oscillations of Mass/Spring System- Energy of a Simple Harmonic Oscillator.

Module II Linear systems and Normal Modes- Two Coupled Pendulums- Systematic Method of Normal Modes- Matrix methods-Longitudinal Vibrations Modes-Transverse Vibrations-Energy of Coupled Systems and Normal co-ordinates-Coupled Electrical Oscillators. Systems with Many Degrees of Freedom-The Normal Modes in the Continuum limit-Vibrations of Taut String-Continuum model-Transverse oscillations of a String free at one end-Longitudinal Oscillations- Fourier Analysis

Module III Harmonic traveling waves- Standing waves-Dispersion and Group Velocity-Energy Transport by traveling wave- Superposition of harmonic waves Interference- The Superposition Principle-The interference between two point sources- Interference Experiments- Practical Applications of Interference.

Module IV Diffraction- Huygens- Fresnel Principle- Diffraction through a single slit- Diffraction through a Circular Aperture- Fraunhofer Diffraction through a Double slit- Diffraction Grating.
Students will have to complete a set of experiments complementing the classroom teaching.

Text Book:

1. A First course in Vibration and Waves, Mohammed Samiullah, Oxford University Press (2015) (Chapters 1 - 4,6,9,10).

Reference Books:

1. Physics of Waves and Oscillations, H. J. Pain, Wiley (2005) (Chapter 10).
2. Vibration and Waves, The M.I.T Introductory Physics Series, A.P.French, W.W. Norton & Company (1971)
3. Optics, E. Hecht, 4th Edition, Pearson education (2009) (Chapters 3-5).

24-807-0202: Thermodynamics

Credits: 4
Academic Level: 100
Hours per week: L - 4, T - 0, P - 0. Total hours per semester : L - 60

Course Objectives:

This course introduces basics of thermal physics to the students. The course aims to make the students understand and apply various concepts of thermodynamics.

Course Outcomes:

CO	CO Statement	CL
CO1	Demonstrate an understanding of the terminology, concepts and principles of thermal physics	Understand
CO2	Develop basics of Kinetic theory of gases	Understand
CO3	Demonstrate an understanding of basics of thermal transport	Understand
CO4	Demonstrate an understanding of laws of Thermodynamics	Understand
CO5	Demonstrate an understanding of various thermodynamic potentials and their uses	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	2	0	1
CO2	2	1	2	2	0
CO3	3	1	2	0	0
CO4	3	1	2	0	1
CO5	3	1	2	0	0

Module I Introductory material: Heat and heat capacity, basic probability, thermal equilibrium. Kinetic theory of gases: Maxwell-Boltzmann distribution, Pressure, Molecular effusion, mean free path and collisions.

Module II Transport and thermal diffusion: Transport properties in gases, The thermal diffusion equation. The first law of thermodynamics: Energy, Isothermal and adiabatic processes.

Module III The second law of thermodynamics: Heat engines and the second law, entropy and the second law.

Module IV Thermodynamic potentials: Internal energy, Enthalpy, Helmholtz function, Gibbs function, Maxwell's relations. Third law of thermodynamics.

Text Book:

1. Concepts in thermal physics, S.J. Blundell and K. M. Blundell, Oxford University Press (2008). (Chapters 1-16, Chapter-18)

Reference Books:

1. Statistical Physics, F. Reif, Berkeley Physics Course, Volume 3, Tata- McGraw-Hill (2008).
2. Heat and Thermodynamics, M. Zemansky and R. Dittman, 7th Edition, McGraw-Hill (1997).
3. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters 17-20).

24-807-0203: Oscillations in Nature

Credits: 3
Academic Level: 100
Hours per week: L - 3, T - 0, P - 0. Total hours per semester : L - 45

Course Objective:

To impart the basic properties of oscillations and waves and to understand the interference and diffraction of light.

Course Outcome:

CO	CO Statement	CL
CO1	To introduce the mathematical foundation of Mechanics, complex numbers and oscillatory motion	Understand
CO2	To understand the concepts of oscillations of systems with more than one degree of freedom	Understand
CO3	To understand the concept of waves and comprehend the idea of interference of light	Understand
CO4	To understand diffraction of light	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	0	3	3	0	0
CO2	0	3	3	0	0
CO3	2	3	2	1	0
CO4	2	3	2	1	0

Module I Review of Mechanics- Complex Numbers- Free Oscillations- One degree of freedom-Stable equilibrium and Restoring Force- Free oscillations of Mass/Spring System- Energy of a Simple Harmonic Oscillator.

Module II Linear systems and Normal Modes- Two Coupled Pendulums- Systematic Method of Normal Modes- Matrix methods-Longitudinal Vibrations Modes-Transverse Vibrations-Energy of Coupled Systems and Normal co-ordinates-Coupled Electrical Oscillators. Systems with Many Degrees of Freedom-The Normal Modes in the Continuum limit-Vibrations of Taut String-Continuum model-Transverse oscillations of a String free at one end-Longitudinal Oscillations- Fourier Analysis

Module III Harmonic traveling waves- Standing waves-Dispersion and Group Velocity-Energy Transport by traveling wave- Superposition of harmonic waves Interference- The Superposition Principle-The interference between two point sources- Interference Experiments- Practical Applications of Interference.

Module IV Diffraction- Huygens- Fresnel Principle- Diffraction through a single slit- Diffraction through a Circular Aperture- Fraunhofer Diffraction through a Double slit- Diffraction Grating.

Text Book:

1. A First course in Vibration and Waves, Mohammed Samiullah, Oxford University Press (2015) (Chapters 1 - 4,6,9,10).

Reference Books:

1. Physics of Waves and Oscillations, H. J. Pain, Wiley (2005) (Chapter 10).
2. Vibration and Waves, The M.I.T Introductory Physics Series, A.P.French, W.W. Norton & Company (1971)
3. Optics, E. Hecht, 4th Edition, Pearson education (2009) (Chapters 3-5).

Semester III

24-807-0301: Basic Mathematical Physics

Credits: 4
Academic Level: 200
Hours per week: L - 3, T - 0, P - 2. Total Hours per semester: L - 45, P - 30

Course Objective:

This course introduces basic mathematical tools used in physics to the students. The course aims to prepare the students for understanding and applying various mathematical formalisms used in physics.

Course Outcome:

CO	CO Statement	CL
CO1	Understand the basics of linear algebra and its applications in physics and engineering	Understand
CO2	Solve basic problems in probability, understand Binomial and Poisson probability distributions and solve basic problems in sample statistics	Apply
CO3	Acquire skill to solve first order and second order ordinary differential equation	Apply
CO4	Demonstrate an understanding of Heaviside unit step function and Dirac delta function, an understanding of Fourier series and its applications, use integral transforms like Fourier and Laplace transform to solve ordinary differential equations with constant coefficientst	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	1	0	1
CO2	2	3	2	0	0
CO3	2	3	1	0	0
CO4	2	3	1	0	0

Module I Matrices and vector spaces: Vector spaces, linear operators, matrices, basic matrix algebra, functions of matrices, transpose, Hermitian conjugate, trace, determinant, inverse and rank. Special types of square matrices, Eigenvectors and eigenvalues, Change of basis and similarity transformation, diagonalisation, simultaneous linear equations.

Module II First order ordinary differential equations: General form of solution. First degree first order equations. Separable- variable equations, exact equations, inexact equations, integrating factors, linear equations, homogeneous equations, isobaric equations, Bernoulli's equation, miscellaneous equations. Solve second order differential equations with constant coefficients.

Module III Heaviside unit step and Dirac delta function. Fourier series, general properties, applications. Integral transforms: Fourier transforms, inversion theorem, Fourier transform of derivatives, convolution theorem. Elementary Laplace transforms, Laplace transform of derivatives, inverse Laplace transforms, solution of ordinary differential equations with constant coefficients.

Module IV Probability and statistics: Venn diagrams, probability, permutations and combinations, random variables and distributions, properties of distributions, important discrete distributions, Binomial, geometric and Poisson distributions. Experiments samples and populations, sample statistics, estimators and sampling distributions.
Students will have to complete a set of computer experiments complementing the classroom teaching.

Text Books:

1. K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical methods for physics and engineering, Cambridge Universality Press (2006).

2. Tai L. Chow, Mathematical Methods for Physicists. A concise introduction, Cambridge University Press (2008).

3. George Arfken, Mathematical Methods for Physicists, Fourth (Prism Indian) 7th Edition, Elsevier (2012).

24-807-0302: Introductory Quantum Physics

Credits: 4
Academic Level: 200
Hours per week: L - 4, T - 0, P - 0. Total hours per semester : L - 60

Course Objective:

The course aims to develop an understanding of the theoretical framework of Quantum Mechanics and its applications.

Course Outcome:

CO	CO Statement	CL
CO1	Learn the experiments and models that lead to the development of quantum mechanics	Understand
CO2	Understand the atomic structure and the need for quantum mechanics	Understand
CO3	Understand the framework of quantum mechanics and solve elementary problems	nderstand, Apply
CO4	Learn to solve advanced problems in quantum mechanicst	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	0	1	0	1
CO2	2	2	1	1	0
CO3	2	2	1	0	1
CO4	3	3	2	0	0

Module I Review of Particle properties of waves and wave properties of matter - blackbody radiation, photoelectric effect, De Broglie waves, Describing a wave, waves of probability, phase and group velocities, particle diffraction, particle in a box, uncertainty principle - Gaussian and the uncertainty principle.

Module II Atomic structure: Electron orbits - the planetary model and its failure, Atomic spectra - spectral series, Review of the Bohr atom, Energy levels and spectra, Quantization of the atomic world, Nuclear motion, atomic excitation.

Module III The wave function, Review of the classical wave equation, Schrodinger's equation, Probability, Normalization, Well-behaved wavefunction; linearity and superposition, probability, expectation values, operators for energy and momentum, steady state equation, particle in a box - energy and momentum, Tunnel Effect

Module IV Harmonic oscillator - Analytic Method, Free particle, The schrodinger equation for Hydrogen Atom, Separation of variables, Quantum numbers, Electron probability density, angular variation of probability,

Text Books:

1. Concepts of Modern Physics, Arthur Beiser, Tata McGraw-Hill, 7th Edition, (2015).
2. Introduction to Quantum Mechanics, D. Griffiths, 2nd Edition, Cambridge University (2017).
3. Quantum Physics, H. C. Verma, Surya Publications, 2nd Edition (2009).
4. University Physics, H.D Young and R.A. Freedman, 12th Edition, Pearson (2009).

24-807-0303: Quantitative Techniques in Physics

Credits: 3
Academic Level: 200
Hours per week: L - 3, T - 0, P - 0. Total Hours per semester: L - 45

Course Objectives

This course introduces basic mathematical tools used in physics to the students. The course aims to prepare the students for understanding and applying various mathematical formalisms used in physics.

Course Outcomes

Upon completion of this course, a student should be able to -

CO	CO Statement	CL
CO1	Understand the basics of linear algebra and its applications in physics and engineering	Understand
CO2	Solve basic problems in probability, understand Binomial and Poisson probability distributions and solve basic problems in sample statistics	Apply
CO3	Acquire skill to solve first order and second order ordinary differential equation	Apply
CO4	Demonstrate an understanding of Heaviside unit step function and Dirac delta function, an understanding of Fourier series and its applications, use integral transforms like Fourier and Laplace transform to solve ordinary differential equations with constant coefficientst	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	1	0	1
CO2	2	3	2	0	0
CO3	2	3	1	0	0
CO4	2	3	1	0	0

Module I Matrices and vector spaces: Vector spaces, linear operators, matrices, basic matrix algebra, functions of matrices, transpose, Hermitian conjugate, trace, determinant, inverse and rank. Special types of square matrices, Eigenvectors and eigenvalues, Change of basis and similarity transformation, diagonalisation, simultaneous linear equations.

Module II First order ordinary differential equations: General form of solution. First degree first order equations. Separable- variable equations, exact equations, inexact equations, integrating factors, linear equations, homogeneous equations, isobaric equations, Bernoulli's equation, miscellaneous equations. Solve second order differential equations with constant coefficients.

Module III Heaviside unit step and Dirac delta function. Fourier series, general properties, applications. Integral transforms: Fourier transforms, inversion theorem, Fourier transform of derivatives, convolution theorem. Elementary Laplace transforms, Laplace transform of derivatives, inverse Laplace transforms, solution of ordinary differential equations with constant coefficients.

Module IV Probability and statistics: Venn diagrams, probability, permutations and combinations, random variables and distributions, properties of distributions, important discrete distributions, Binomial, geometric and Poisson distributions. Experiments samples and populations, sample statistics, estimators and sampling distributions.

Text Books:

1. K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical methods for physics and engineering, Cambridge Universality Press (2006).

2. Tai L. Chow, Mathematical Methods for Physicists. A concise introduction, Cambridge University Press (2008).

3. George Arfken, Mathematical Methods for Physicists, Fourth (Prism Indian) 7th Edition, Elsevier (2012).

Semester IV

24-807-0401: Classical Mechanics and Relativity

Credits: 4
Academic Level: 200
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

This intends to develop the basics methods of analysing non-inertial frames, Rigid body dynamics, elements of fluid dynamics and special theory of relativity.

Course Outcome:

CO	CO Statement	CL
CO1	Understand the motion within a non-inertial frame	Understand
CO2	Enable the students to apply the Newtons law in understanding the basics of rigid body dynamics	Apply
CO3	Aquire basic knowledge in fluid dynamics	Understand
CO4	Get a hands on the preliminaries of special theory of relativity	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	2	0	0
CO2	1	1	2	0	0
CO3	1	2	2	0	0
CO4	1	2	2	0	0

Module I Concepts of Inertial frames, force and mass.Galilean transformations and Galilean invariance. Solution of the equations of motion (E.O.M.) in simple force fields in one, two and three dimensions using cartesian, cylindrical polar and spherical polar coordinate systems. Non-inertial systems: - Idea of fictitious forces - Physics in a rotating coordinate system - Equation of motion with respect to a uniformly rotating frame - Centrifugal and Coriolis forces

Module II The Rigid Body: Constraints defining the rigid body. Degrees of freedom for a rigid body; (b) Relation between Angular momentum and Angular Velocity: Moment of Inertia Tensor. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies.

Module III Basics Lagrangian formulation: definition of Lagrangian with examples- Lagrangian of free particle, Lagrangian of harmonic oscillator, Lagrangian of freely falling particle. Concept of the principle of least action: definition of action, principle of leat action, variation of action for a particle moving in a potential V (x) and derivation of Newton's law of motion.

Module IV Review of *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. Mass-energy Equivalence.*
Transformation of Energy and Momentum. Invariant interval, Space-time diagrams. Proper time and Proper velocity. Relativistic energy and momentum - Four-vectors, Four momentum. Conservation of four momentum. Force in relativity, Force four-vector

Text Books:

1. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw- Hill
2. Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
3. Fundamentals of Physics I, R. Shankar, Yale University Press, London (2019)
4. Introduction to Special Relativity, R. Resnick, 2010, John Wiley and Sons
5. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., Pearson Education

Reference Books:

1. Mechanics, C. Kittel, W.D. Knight, M.A. Ruderman, C.A. Helmholz and B.J. Moyer, Berkeley Physics Course Vol 1, Tata McGraw-Hill Ltd (2008). (Chapters 1-9)
2. Elements of Properties of Matter, D. S. Mathur, S. Chand & Co (2008).

24-807-0402: Electricity and Magnetism-I

Credits: 4
Academic Level: 200
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

This course will help in understanding basic concepts of electricity and magnetism and their applications.
Basic course in electrostatics will equip the student with required prerequisites to understand electrodynamics phenomena.

Course Outcome:

CO	CO Statement	CL
CO1	Demonstrate Coulomb's law for the electric field, and apply it to systems of point charges	Understand
CO2	Apply Gauss's law of electrostatics to solve a variety of problems	Understand
CO3	Articulate knowledge of electric potential and electric potential energy and different electrical measuring instruments	Understand
CO4	Demonstrate a working understanding of direct current circuits and characteristics of R- C and R-L circuits	Understand
CO5	Describe the magnetic field produced by moving charge and various applications of motion of charged particles in the magnetic field	Apply
CO6	Explain Faraday-Lenz laws to articulate the relationship between electric and magnetic fields	Apply
CO7	Calculate the energy stored in a magnetic field	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	0	0
CO2	3	1	2	0	0
CO3	3	1	2	0	0
CO4	3	1	2	0	0
CO5	3	1	2	0	0
CO6	3	1	2	0	0
CO7	3	1	2	0	0

Module I Electrostatics - Charges and fields: Electric Charge, Conservation of Charge, Quantization of Charge, Coulomb's Law, The Electric Field, and Electric forces, Electric field calculations, Electric field lines, electric dipoles, Charge and electric Flux, Gauss's Law, Field of a Spherical Charge Distribution, Field of a uniform Line Charge, Field of an infinite plane sheet of charge

Module II The electric potential: Electric Potential Energy, Electric Potential Energy in a Uniform Field, Electric Potential Energy of Two Point Charges, Electric Potential Energy with Several Point Charges, Calculating Electric Potential, Finding Electric Potential from Electric Field, the electric potential of a charged conducting sphere, electric potential of an infinite line charge, potential of a ring of charge and line of charge, equipotential Surfaces, the potential gradient

Module III Electric currents: Electric Current and Current Density, Resistivity, Resistance, Electromotive Force, and Circuits, Energy and power in electric circuits, Electrical Conductivity and Ohm's Law, The Physics of Electrical Conduction, Conduction in Metals, Semiconductors, Direct current circuits, Resistors in series and parallel, Kirchhoff's rules, Electrical Measuring Instruments, R-C circuits The fields of moving charges: Magnetic Forces, Measurement of Charge in Motion, Invariance of Charge, Electric Field Measured in Different Frames of Reference, Field of a Point Charge Moving with Constant Velocity, Field of a Charge That Starts or Stops, Force on a Moving Charge, Interaction between a Moving Charge and Other Moving Charges.

Module IV Magnetic field and electromagnetic induction: Magnetic Field, the motion of charged particles in a magnetic field- applications, the magnetic force on a current-carrying conductor, Hall effect, magnetic field of a moving charge, magnetic field of a current element, magnetic field of a straight current-carrying conductor, magnetic field of a circular loop, Electromagnetic induction: Faraday's law, Lenz's law, Mutual Inductance, Self-inductance, Energy Stored in the Magnetic Field, R-L circuits.

Text Books:

1. Electricity and Magnetism, Purcell, Berkeley Physics Course Volume 2, Tata McGraw-Hill Ltd (2008). (Chapters 1-2, Chapters 4-7).
2. University Physics, H.D Young and R.A. Freedman, 12th Edition, Pearson (2009).(Ch 21- 23, 25-30)

Reference Books:

1. Introduction to Electrodynamics, D. J. Griffiths, Pearson Education India, 4th edition (2015).
2. The Feynman lectures Volume II, Narosa (2003).
3. Fundamentals of Physics, Halliday, Resnik and Walker, John Wiley and Sons Inc, 11th Edition.

24-807-0403: Thermal Physics

Credits: 4
Academic Level: 200
Hours per week: L - 4, T - 0, P - 0. Total hours per semester : L - 60

Course Objectives:

This course introduces basics of thermal physics to the students. The course aims to make the students understand and apply various concepts of thermodynamics.

Course Outcomes:

CO	CO Statement	CL
CO1	Demonstrate an understanding of the terminology, concepts and principles of thermal physics	Understand
CO2	Develop basics of Kinetic theory of gases	Understand
CO3	Demonstrate an understanding of basics of thermal transport	Understand
CO4	Demonstrate an understanding of laws of Thermodynamics	Understand
CO5	Demonstrate an understanding of various thermodynamic potentials and their uses	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	2	0	1
CO2	2	1	2	2	0
CO3	3	1	2	0	0
CO4	3	1	2	0	1
CO5	3	1	2	0	0

Module I Introductory material: Heat and heat capacity, basic probability, thermal equilibrium. Kinetic theory of gases: Maxwell-Boltzmann distribution, Pressure, Molecular effusion, mean free path and collisions.

Module II Transport and thermal diffusion: Transport properties in gases, The thermal diffusion equation. The first law of thermodynamics: Energy, Isothermal and adiabatic processes.

Module III The second law of thermodynamics: Heat engines and the second law, entropy and the second law.

Module IV Thermodynamic potentials: Internal energy, Enthalpy, Helmholtz function, Gibbs function, Maxwell's relations. Third law of thermodynamics.

Text Book:

1. Concepts in thermal physics, S.J. Blundell and K. M. Blundell, Oxford University Press (2008). (Chapters 1-16, Chapter-18)

Reference Books:

1. Statistical Physics, F. Reif, Berkeley Physics Course, Volume 3, Tata- McGraw-Hill (2008).
2. Heat and Thermodynamics, M. Zemansky and R. Dittman, 7th Edition, McGraw-Hill (1997).
3. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters 17-20).

24-807-0404: Science Communication

Credits: 3
Academic Level: 200
Hours per week: L - 2, T - 1, P - 2. Total Hours per semester: L - 30, T - 15, P - 30

Course Objective

This course intends to develop communication and data presentation skills (oral, written, and presentation) of the students which will enable them to present scientific ideas clearly and concisely whether in an interview or in a scientific paper or presentation. The course explores various aspects of science communication, including communicating science to the general public, media, policymakers, and other scientists. Students will learn about different communication strategies, techniques, and tools to effectively communicate complex scientific information to a broad audience. The course will be mostly activity based.

Course Outcome

CO	CO Statement	CL
CO1	Present data and results of an experiment accurately and effectively	Apply
CO2	Understand the importance of effective science communication	Understand
CO3	Identify different target audiences and tailor communication strategies to meet their needs	Apply
CO4	Develop skills in writing for diverse audiences and purposes	Apply
CO5	Develop skills in oral presentation and public speaking	Apply
CO6	Understand the ethical considerations in science communication	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	0	0	2	0	3
CO2	0	0	2	0	3
CO3	0	0	2	0	3
CO4	0	0	2	0	3
CO5	0	0	2	0	3
CO6	0	0	2	0	3

Module I (Weeks 1-5) Good lab practices, Quantifying error in experiments and data analysis, Error propagation, Obtaining good statistical accuracy, Central Limit theorem.
Publishing scientific results: The structure of a scientific paper and presentation. Academic ethics & Intellectual property rights.

Module II Week 6 - 7: Writing for diverse audiences and purposes, Writing for the web and social media.
Activity: Developing concise science writing skills: Students have to prepare an article for the common man explaining a given scientific research paper/topic to the public.
Week 8 - 10: Preparing and delivering effective speeches, Engaging with the audience.
Activity: Students have to prepare and record a 5-10 min podcast explaining a scientific idea to the public.

Week 11-13: Handling questions and interviews
Activity: Each student takes turns attending a 10 min interview with other students on selected topics.
Week 14-16: Preparing and delivering effective presentations, Using visual aids to communicate science, Principles of data visualization.
Activity: Students have to prepare a 10 min PowerPoint presentation on a given topic.
Week 17-18: Final Project: Prepare a scientific report on an experiment the students performed in the lab with abstract, introduction, content, results and references.

Text Books:

1. Science Communication - A Practical Guide for Scientists, L. Bowater, K. Yeoman, Wiley

2. John Durant, and Bina Venkataraman. STS.034 Science Communication: A Practical Guide. Fall 2011. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu. License: Creative Commons BY-NC-SA.

3. Effective science communication, S.Illingworth and S. Allen, IOP.

4. The Scientist's Guide to Writing: How to Write More Easily and Effectively throughout Your Scientific Career by Stephen B. Heard

5. Communicating Science: A Practical Guide by Gavin Bremner and Alan S. J. King

Semester V

24-807-0501: Basic Electronics

Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives:

This course aims to provide the fundamental understanding of analog and digital electronic components as well as the skills necessary to analyze and design basic electronic circuits.

Course Outcomes:

CO	CO Statement	CL
CO1	Familiarise with circuit analysis, detailed understanding of diode characteristics and applications	Understand
CO2	Understanding the transistor characteristics and different types of amplifiers	Understand
CO3	Understanding the basics of operational amplifiers	Understand
CO4	Understanding basics of digital electronics	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	1	2	0
CO2	1	0	1	2	0
CO3	1	0	1	2	0
CO4	1	0	1	2	0

Module I Ohms law, Kirchhoff's law- Ideal voltage and current sources- Thevenin's and Norton's theorem, Maximum power transfer theorem, Basic band theory of solids, Diode theory, forward and reverse-biased junctions, reverse-bias breakdown, load line analysis, diode applications - Limiters, clippers, clampers, voltage multipliers, half wave and full wave rectification, Special purpose diodes - Zener diode, Varactor, light emitting diodes, Laser diodes.

Module II Transistor fundamentals, Review of the characteristics of transistor in CE and CB configurations, Regions of operation (active, cut off and saturation), transistor biasing, Current gains α and β. Relations between α and β, dc load line and Q point, AC analysis of BJT, Single and multi-stage-RC coupled transistor amplifiers, Concept of feedback, negative and positive feedback, Transistor oscillator circuits - phase shift, Hartley Oscillator, Colpitt oscillator, Field-Effect Transistors (FET).

Module III Ideal operational amplifier, practical Op Amp circuits, differential and Common mode operation, Inverting & Non-Inverting Amplifier, voltage follower, inverter, Op-Amp applications- Adder, Differentiator, and Integrator.

Module IV Number System – Introduction to binary, octal, decimal & hexadecimal systems, representation of negative numbers, 1's, 2's complement and their arithmetic, Boolean algebra – Boolean theorems, minimization of Boolean function, K-Map minimization. Basic logic gates, Boolean functions realization using logic gates, half & full adder, subtractor, Introduction to sequential logic, introduction to flip-flop, RS, D, T, JK flip-flops, race around condition, Master-slave JK flip-flops, flip-flop clocked sequential circuits.

Text Books:

1. Modern physics, Arthur Beiser, 6th Edition, Tata McGraw-Hill (2006). (Chapter-10).
2. A.S. Sedra & K.C.Smith, Microelectronics Circuits, Oxford University Press (1997).
3. Leach, Malvino, and Saha, Digital Principles and Applications, 5th Edition, McGraw Hill Education (1994).
4. A. Anand Kumar, Fundamentals of Digital Circuits (3rd Edition), PHI Learning Pvt. Ltd., New Delhi (2014).

Reference Books:

1. Robert L. Boylestad & Louis Nashelsky, Electronic Devices & Circuit Theory.
2. William Kleitz, Digital Electronics, Prentice Hall International Inc.
3. V. K. Metha, Rohit Metha, Principles of Electronics (S. Chand).
4. R. P. Jain, Thomas L. Floyd, Digital Fundamentals, Pearson Education (2005).

24-807-0502: Electricity and Magnetism - II

Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

In paper I of this subject we have introduced the basic of electricity and magnetism. In this paper the main objective is to continue the effort in understanding further like properties of dipole etc and also understanding how these two fields have been united into a single object called electromagnetic field.

Course Outcome:

CO	CO Statement	CL
CO1	Familiarise with the basics of electric field in conductors	Understand
CO2	Familiarise with dielectric properties and allied phenomenon called electric polarisation	Understand
CO3	Understanding mainly the alternating current and displacement current and their significance	Understand
CO4	Understanding the magnetic properties of matter	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	0	1	1	1
CO2	2	2	1	1	1
CO3	1	2	1	2	1
CO4	2	2	3	2	1

Module I Electric fields around conductors: Conductors and Insulators, Conductors in the Electrostatic Field, The General Electrostatic Problem, Uniqueness Theorem, Capacitance and Capacitors, Potentials and Charges on Several Conductors, Energy Stored in a Capacitor.

Module II Electric fields in matter: Dielectrics, The Moments of a Charge Distribution, The Potential and Field of a Dipole, The Torque and the Force on a Dipole in an External Field, Atomic and Molecular Dipoles, Induced Dipole Moments, Permanent Dipole Moments. The Electric Field Caused by Polarized Matter, The Field of a Polarized Sphere, A Dielectric Sphere in a Uniform Field, The Field of a Charge in a Dielectric Medium and Gauss's Law, A Microscopic View of the Dielectric Polarization in Changing Fields, The Bound-Charge Current, An Electromagnetic Wave in a Dielectric.

Module III Alternating current circuits: A Resonant Circuit, Alternating Current, Alternating-Current Networks, Admittance and Impedance, Power and Energy in Alternating-Current Circuits. Maxwell's equations and electromagnetic waves: The Displacement Current, Maxwell's Equations, An Electromagnetic Wave, Other Waveforms; Superposition of Waves, Energy Transport by Electromagnetic Waves, How a Wave Looks in a Different Frame.

Module IV Magnetic fields in matter: How Various Substances Respond to a Magnetic Field, The Absence of Magnetic "Charge", The Field of a Current Loop, The Force on a Dipole in an External Field, Electric Currents in Atoms, Electron Spin and Magnetic Moment, Magnetic Susceptibility, The Magnetic Field Caused by Magnetized Matter, The Field of a Permanent Magnet, Free Currents and the Field H, Ferromagnetism.

Text Books:

1. Electricity and Magnetism, Purcell, Berkeley Physics Course Volume 2, Tata McGraw-Hill Ltd (2008). (Chapter 3, Chapters 8-11).

Reference Books:

1. Introduction to Electrodynamics, D. J. Griffiths, 4th Edition, Cambridge University Press (2017).
2. The Feynman lectures on Physics Volume II, Narosa (2003).
3. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009).

24-807-0503: Introduction to Quantum Mechanics

Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 0, P - 0. Total hours per semester : L - 60

Course Objective:

The course aims to develop an understanding of the theoretical framework of Quantum Mechanics and its applications.

Course Outcome:

CO	CO Statement	CL
CO1	Learn the experiments and models that lead to the development of quantum mechanics	Understand
CO2	Understand the atomic structure and the need for quantum mechanics	Understand
CO3	Understand the framework of quantum mechanics and solve elementary problems	nderstand, Apply
CO4	Learn to solve advanced problems in quantum mechanicst	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	0	1	0	1
CO2	2	2	1	1	0
CO3	2	2	1	0	1
CO4	3	3	2	0	0

Module I Review of Particle properties of waves and wave properties of matter - blackbody radiation, photoelectric effect, De Broglie waves, Describing a wave, waves of probability, phase and group velocities, particle diffraction, particle in a box, uncertainty principle - Gaussian and the uncertainty principle.

Module II Atomic structure: Electron orbits - the planetary model and its failure, Atomic spectra - spectral series, Review of the Bohr atom, Energy levels and spectra, Quantization of the atomic world, Nuclear motion, atomic excitation.

Module III The wave function, Review of the classical wave equation, Schrodinger's equation, Probability, Normalization, Well-behaved wavefunction; linearity and superposition, probability, expectation values, operators for energy and momentum, steady state equation, particle in a box - energy and momentum, Tunnel Effect

Module IV Harmonic oscillator - Analytic Method, Free particle, The schrodinger equation for Hydrogen Atom, Separation of variables, Quantum numbers, Electron probability density, angular variation of probability,

Text Books:

1. Concepts of Modern Physics, Arthur Beiser, Tata McGraw-Hill, 7th Edition, (2015).
2. Introduction to Quantum Mechanics, D. Griffiths, 2nd Edition, Cambridge University (2017).
3. Quantum Physics, H. C. Verma, Surya Publications, 2nd Edition (2009).
4. University Physics, H.D Young and R.A. Freedman, 12th Edition, Pearson (2009).

24-807-0504: Optics and Spectroscopy

Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

This course aims to provide a comprehensive understanding of the principles and applications of optics and spectroscopy.

Course Outcome:

CO	CO Statement	CL
CO1	Study and solve problems in wave propagation	Apply
CO2	Use transverse nature of light to study optical phenomena and devices	Apply
CO3	Explain light amplification, basics of fibre optics, and nonlinear optical properties	Understand
CO4	Assimilate concepts of spectroscopy and applications	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	1	0	1
CO2	2	1	1	0	1
CO3	2	2	3	2	1
CO4	2	2	2	1	1

Module I Wave Optics Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Electromagnetic nature of light. Modulation, Superposition of two harmonic and travelling waves, Modulation velocity, Phase velocity and Group velocity, AM Radio waves, Electromagnetic radiation in vacuum, non-dispersive waves, waves in the ionosphere, surface waves in water. Pulses, Time-bandwidth product, solution to the pulse with square frequency spectrum.

Module II Polarization, Interference, and Diffraction Polarized light, polarization through dichroism, birefringence, scattering and reflection. Linear polarizers, wire-grid polarizer, polaroid, Nicol prism, retarders, full, half and quarter wave plates. Induced optical effects, Photoelasticity, Faraday effect, Cotton-Muton effect, Kerr effect and Pockels' effect. Optical modulators. Theory of interference of light, Michelson Interferometer, Lloyd's Mirror, Fresnel's Biprism. Multiple-beam interference, Fabry-Perot interferometer, applications to single and multilayer films, Fresnel diffraction, Fraunhofer diffraction: Single slit. Double slit. Multiple slits. Diffraction grating.

Module III Lasers, Nonlinear Optics, and Fibre Optics Absorption and emission, Stimulated emission, Population inversion, Einstein coefficients, Methods of Producing population inversion, Solid state lasers (Ruby, Nd:YAG), Gas lasers (He-Ne, CO 2), Q-switching, Mode-locking. Nonlinear optics (basics), Optical rectification, harmonic generation, Frequency mixing, two- photon absorption, self-focusing. Structure of an Optical Fibre, Liquid phase fibre fabrication, Ray propagation in step-index fibres, Ray propagation in graded-index fibres, Effect of material dispersion.

Module IV Basics of Spectroscopy Electromagnetic spectrum, Blackbody spectrum, Boltzmann population distribution, Einstein coefficients, Structure of atoms, Atomic quantum numbers, fine structure in Hydrogen atom, Normal and Anomalous Zeeman effect. Overview of molecular spectroscopy-classification of polyatomic molecules, Rotational spectra of rigid diatomic molecule, Applications of microwave spectroscopy, vibrational spectra of diatomic molecule, Introduction to Raman spectroscopy and instrumentation.

Text Books:

1. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, Tata McGraw-Hill (2007).
2. Optics (4 th Ed.) by E Hecht and A R Ganesan, Pearson (2019)
3. Introduction to Modern Optics, G R Fowles, Dover Publications (1975)
4. Optics, Ajoy Ghatak, Tata McGraw Hill (2008)
5. Fiber Optics and Optoelectronics, R P Khare, Oxford University Press (2015)
6. Concepts of Modern Physics, Arthur Beiser, Tata McGraw-Hill, 7th Edition, (2015).
7. Fundamentals for Molecular Spectroscopy, 4th Ed., C. N. Banwell and E. M. McCash, McGraw Hill Education (2017).

24-807-0505: Numerical and Computational Physics

Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

This course provides an introduction to the numerical techniques and computational methods used in physics. Applications will be drawn from various areas of physics, such as classical mechanics, quantum mechanics, and statistical physics.

Course Outcome

CO	CO Statement	CL
CO1	To be able to apply computational techniques to solve physics problems	Apply
CO2	To be able to analyze and interpret simulation data	Analyse
CO3	To develop an understanding of numerical methods used in physics	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	0	1	2	1	0
CO2	1	2	1	0	0
CO3	0	2	1	0	0

Module I Programming language: Introduction to Python/Matlab/Octave programming, IDEs for programming, variables, input/output, loading and saving data, loops, branches and control flow, matrix and array operations.Sub programs, array of dimensional variables, subroutines, functions, modular programming, built-in functions and modules. Data Visualization; Plotting functions, scatter plot, 2D plots, Heatmaps, Histograms

Module II Solving algebraic equations: Newton-Raphson method, Application to time of flight calculation. Finding the minimum/maximum of a function, interpolation, linear algebra and Fourier series/transform. Numerical differentiation: Calculating first and second derivative numerically. Numerical integration: Trapezoidal and Simpson's rule.

Module III Solving ordinary differential equations: Eulers method, RK method, Application to simple harmonic motion, motion in a viscous medium, projectile motion. Partial differential equations (PDEs), Finite difference methods, Application to the heat equation.

Module IV Data analysis techniques, Curve fitting, Monte Carlo methods, obtaining statistics from data, Random number generation, Simulating experimental data - simple pendulum experiment, trajectory of a projectile, Application to calculating integrals, Application to statistical mechanics

Text Books:

1. Computational Physics by Mark Newman and Gergely Toth
2. An Introduction to Computational Physics by Tao Pang
3. Numerical Methods for Physics by Alejandro L. Garcia

24-807-0506: Introduction to Instrumentation, Mechanical design and Workshop for Undergraduates

Credits: 3
Academic Level: 200
Hours per week: L - 2, T - 1, P - 2. Total Hours per semester: L - 30, T - 15, L - 30

Course Objective:

The course aims to equip students with basic knowledge and hands-on experience in using various sensors, interfacing with microcontrollers, electrical measurements and 3D printing techniques. The course will provide them with the basics of mechanical design and introduce them to mechanical workshop practices.

Course Outcome:

CO	CO Statement	CL
CO1	Understand microcontroller programming and circuit design	Understand
CO2	Understand the fundamentals of electrical measurement techniques in physics research	Understand
CO3	Learn mechanical design with computer-aided design software specifically for additive manufacturing (3D printing)	Apply
CO4	Familiarize and hands-on training in mechanical and electrical workshops	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	0	1	3	3	0
CO2	0	1	3	3	0
CO3	0	1	3	0	0
CO4	0	1	3	0	0

Module I Microcontroller-based circuits: Introduction to Arduino-based microcontroller circuits and programming, interfacing sensors/ transducers and data acquisition and feedback system design, basics of IoT.

Module II Instrument accuracy, precision, sensitivity, range. Errors in measurements, introduction to various electrical measurement devices and their principles of operation, Electrical measurements: Measurement emphasis on two-probe, four-probe, dc and ac measurement basics.

Module III Mechanical design using CAD Software- Introduction to Computer-Aided Design (CAD) Introduction to 3D printing technologies and their applications, machining processes: milling, turning, drilling, etc.CNC machining and programming.

Module IV Lab/Workshop practice: Familiarizing basic workshop tools, heavy equipment. Electrical and Electronics Workshop: Basics of electrical wiring, ground etc, PCB design, Soldering, Lab Safety training.

Text Books:

1. Arduino Cookbook, Michael Margolis, O'Reilly Media (2011).
2. Experimental Techniques In Condensed Matter Physics At Low Temperatures by Robert C. Richardson (Editor),CRC Press 1st edition (2018).
3. 3D Modeling and Printing With Tinkercad: Create and Print Your Own 3D Models 1st Edition, James Floyd Kelly(author), Que Pub (2014).
4. Workshop Technology, Chapman W.A.J, 4-th edition, CBS Publishers(2001).
5. Other references includes manuals of equipment, application notes and research journals.

Semester VI

24-807-0601: Basic Solid State Physics

Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

Introduce the most basic structure of solid state physics.

Course Outcome

CO	CO Statement	CL
CO1	Understanding the various types crystal structure and their properties	Understand
CO2	Understanding the band structure in crystals	Understand
CO3	Understanding the magnetic properties of solids and also the fundamentals of superconductivity	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	1	0
CO2	3	2	3	1	1
CO3	3	2	3	2	0

Module I Crystal Structure Crystalline and amorphous solids, translational symmetry. Elementary ideas about crystal structure, lattice and bases, unit cell, reciprocal lattice, fundamental types of lattices, Miller indices, lattice planes, simple cubic, f.c.c. and b.c.c. lattices. Laue and Bragg equations. Determination of crystal structure with X-rays.

Module II Structure of solids Different types of bonding - ionic, covalent, metallic, van der Waals and hydrogen. Free electron theory of metals, effective mass, drift current, mobility and conductivity, Wiedemann-Franz law. Hall effect in metals. Band theory of solids, Periodic potential and Bloch theorem, Kronig-Penny model, energy band structure. Band structure in conductors, direct and indirect semiconductors and insulators (qualitative discussions).

Module III Magnetic properties of materials Dia, para and ferro-magnetic properties of solids. Langevin's theory of diamagnetism and paramagnetism. Quantum theory of paramagnetism, Curie's law. Ferromagnetism: spontaneous magnetization and domain structure; temperature dependence of spontaneous magnetisation; Curie-Weiss law, explanation of hysteresis. Superconductivity Introduction (Kamerlingh-Onnes experiment), effect of magnetic field, Type-I and type-II superconductors, Isotope effect. Meissner effect. Heat capacity. Energy gap. Ideas about High-Tc superconductors.

Module IV Lattice vibrations Elastic and atomic force constants; Dynamics of a chain of similar atoms and chain of two types of atoms; optical and acoustic modes; interaction of light with ionic crystals. Einstein's and Debye's theories of specific heats of solids. Dielectric properties of materials Electronic, ionic and dipolar polarizability, local fields, induced and oriented polarization – molecular field in a dielectric; Clausius-Mosotti relation.

Text Books:

1. Solid State Physics, Dekker, A. J., Macmillan (2000).
2. Introduction to Solid State Physics (8th Edition), Charles Kittel, Wiley (2004).
3. Solid state physics, Ashcroft, Neil W. and Mermin, N., Brooks/Cole (1976).
4. Elements of x-ray diffraction (3rd edition), Cullity, B. D. and Stock, Stuart H., Prentice Hall (2001).
5. Elementary Solid State Physics: Principles and Applications, Ali Omar, Pearson (1993).
6. The Oxford solid state basics, Simon, Steven, Oxford University Press (2004).

24-807-0602: Basic Nuclear Physics and Applications

Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives:

The course aims to develop an understanding of the basic concepts of nuclear physics and particle physics. Also, the students will get an idea of different types of nuclear radiation, their interactions with matter, and their applications in our life.

Course Outcomes:

After completing this course the students will be able to

CO	CO Statement	CL
CO1	Understand the basic properties of atomic nucleus, binding energy and elements of nuclear models (Module 1)	Understand
CO2	Familiarise the different types of decays and its properties. (Module 2)	Understand
CO3	Summarize the interaction of radiation with matter and its applications. (Module 3)	Understand
CO4	Classify different types of accelerators and familiaries the elementary particles and its properties.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	1	1	0
CO2	1	2	1	1	0
CO3	1	2	1	1	0
CO4	1	2	1	1	0

Module I Introduction and Basic concepts: The nucleus and its constituents, the N-Z chart, Nuclear mass, Radius, Density, Spin, Parity, Stable Nuclei, Binding energy, Nuclear potential and energy levels, Semi empirical (liquid drop) model, Evidence for shell structure, magic numbers, Nuclear shell model (with the harmonic oscillator potential), spin-orbit coupling.

Module II Radioactivity, Radioactive decay law, Half-life, Types of decays, Alpha emission, Beta emission and electron capture, Gamma emission and internal conversion, Natural Radioactivity, radioactive decay chains, Radioactive Dating, Nuclear Collisions, Cross section, differential cross section and reaction rate, Nuclear reactors and energy production, Breeder reactors.

Module III Interaction of radiation with matter: Heavy charged particles interactions, Bethe-Bloch formula, Energy dependence, Bragg curve, Stopping medium dependence, Absorbed dose, equivalent dose, Gamma rays interactions, photoelectric effect, Compton scattering, Pair production, Applications in tracing, material modification, sterilization, material modification, neutron activation analysis, Diagnostic Nuclear Medicine and Therapeutic Nuclear Medicines: CT, PET, SPECT, MRI.

Module IV Linear and circular accelerators, Interactions and Particles, Leptons, Hadrons, Quarks, Conservation laws and symmetries, Conservation of energy and mass, Conservation of linear momentum and angular momentum, Conservation of Baryon and Lepton numbers, Conservation of strangeness, Conservation of isospin.

Text Books:

1. J. S. Lilley, Nuclear Physics: Principles and Applications, John Wiley (2001).
2. Kenneth S. Krane, Introduction to Nuclear Physics, John Wiley (2008).
3. The particle hunters (2nd Revised Edition), Yuval Ne'eman & Yoram Kirsh, Cambridge University Press (1996).

Reference Books:

1. Herald A. Engel, Introduction to Nuclear Physics, Addison Wesely (1967).
2. Cohen B. L., Concepts of Nuclear Physics, Tata McGraw Hill (2008).

24-807-0603: Basic Skills in Vacuum Technology

Credits: 3
Academic Level: 200
Hours per week: L - 2, T - 1, P - 2. Total Hours per semester: L - 30, T - 15, P - 30

Course Objective

Vacuum technology finds extensive usage across various crucial sectors, including medical, analytical metrology, reliability testing, food sciences, semiconductor manufacturing, and optics, among others. This course is designed to educate upcoming technicians, engineers, and scientists on this essential subject offering a sturdy groundwork for their careers with plentiful opportunities for advancement.

Course Outcome

Upon completion of the course, students should acquire foundational skills in comprehending and managing:

CO	CO Statement	CL
CO1	Rough vacuum systems	Understand, Apply
CO2	High vacuum systems	Understand, Apply
CO3	Ultra-high vacuum systems	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	2	2	0
CO2	1	0	2	2	0
CO3	1	0	2	2	0

Module I Vacuum an enabling technology: what is vacuum? Vacuum as an enabler, benefits of creating vacuum, Behavior of gases: states of matter, gas pressure, kinetic theory of gases, ideal gas law, mean free path, adsorption and desorption, diffusion and permeation, thermal conductivity, vapor pressure.

Module II Introduction to vacuum system-gas loads, throughput, pumping speed and conductance, vacuum systems an overview, schematic symbols and diagrams, simple rough vacuum system, characterizing vacuum systems.

Module III Rough vacuum systems-gas load in rough vacuum regime, rough vacuum pumps, rough vacuum gauges, rough vacuum pump down process, conductance, troubleshooting rough vacuum systems.

Module IV High vacuum and ultrahigh vacuum systems: diffusion pump, turbomolecular pumps, ion getter pumps, titanium sublimation pumps, cryopumps -operating principle, maintenance and applications.

Text Books:

1. Introduction to Vacuum Technology, David M. Hata; Elena V. Brewer; and Nancy J. Louwagie Milne Open Textbooks, Milne Library, State University of New York at Geneseo.

2. Handbook of Vacuum Technology, Karl Jousten, 2016 Wiley-VCH Verlag GmbH & Co. KGaA

Semester VII

24-807-0701: Classical Mechanics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

The course aims to develop an understanding of Lagrangian and Hamiltonian formulation which enables the students for simplified treatments of many complex problems in classical mechanics and provides the foundation for the modern understanding of dynamics. In a detailed way, since this course forms the foundation for the study of many areas of Physics such as Quantum mechanics, it apprises the students about Lagrangian and Hamiltonian formulations. The course aims:

- To define the concepts of Lagrangian Mechanics.
- To interpret the concepts of Hamiltonian Mechanics and explain generating function, canonical transformation, Poisson brackets. To formulate the method of Hamilton-Jacobi techniques.
- To illustrate the dynamics of a rigid body and non-inertial frames of reference.
- To formulate the method of Hamilton-Jacobi and action-angle variable techniques.
- Understanding the basics of non-linear dynamics in physics and their applications

Course Outcome:

CO	CO Statement	CL
CO1	Understanding the drawback of Newtonian formulation of mechanics. Construct Lagrangian for different physical systems and Lagrange's equation of motion and solve it. (Module 1)	Understand
CO2	Understanding the Hamiltonian formalism in solving physics problems and understanding the Poisson bracket method in tackling physical problems. Understanding the Hamiltonian-Jacobi formulation and its applications. (Module 2)	Understand
CO3	Understanding the techniques for solving the problems of rigid body mechanics based on Lagrange's formulation (Module 3)	Understand
CO4	Understanding the basic characteristic features of non-linear dynamics (Module 4)	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	3	0	1
CO2	3	3	3	0	0
CO3	2	2	2	0	1
CO4	2	3	3	0	2

Module I

Lagrangian formulation: Mechanics of a system of particles(brief review)- Constraints - Generalized coordinates - D'Alembert's principle and Lagrange's equations - Calculus of variations and Derivation of Lagrange's equations from it. Symmetry properties and Noether's theorem. Application of Lagrange's equation to Central force problem - equivalent one dimensional problem - classification of orbits - the differential equation for orbits - Kepler problem.

Module II

Hamiltonian Mechanics: Hamilton's equation from variation of principle (Principle of least action with fixed end points), cyclic coordinates. Equations of canonical transformation - examples. Poisson Brackets- Equations of motion , angular momentum Poisson Bracket relations. Hamilton-Jacobi equation - harmonic oscillator problem - Hamilton's characteristic function.

Module III

Rotational dynamics: Independent coordinates of a rigid body. Orthogonal transformations - Euler angles - rigid body equations of motion- angular momentum and kinetic energy of motion about a point- inertia tensor- Solving rigid body problems and Euler equations of motion- torque free motion of a rigid body- symmetric top. Rate of change of a vector, centrifugal and Coriolis forces.

Module IV

Nonlinear dynamics and chaos: Historical overview, FIxed points and stability, Linear stability analysis, Classification of Bifurcations, Chaotic trajectories, Liapunov exponent, Lorentz map, Logistic map: Cobweb diagram; Fixed points, Onset of chaos, Poincare maps, Fractals and dimensionality : Cantor set, Sierpinski carpet. (Sections from Text book 2)

Text Books:

1. H. Goldstein, C. Poole and J. Safko , Classical Mechanics, Third Edition, Pearson (2011).
2. Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering. SH Strogatz, CRC Press, 2018.

Reference Books:

1. V. B. Bhatia , Classical Mechanics, Narosa (1997).
2. Landau and Lifshitz, Mechanics Vol. I, 3rd Edition, Butterworth-Heinemann (1976).
3. Rana and Joag, Classical Mechanics, McGraw-Hill Education (India) Pvt Limited, (2001).

24-807-0702: Electrodynamics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

The course aims to develop the fundamental concepts in classical electrodynamics. For students who are already familiar with the basics of electromagnetism, Maxwell's equations will be introduced and they will be equipped with advanced mathematical methods to tackle various boundary value problems in electrodynamics. By introducing the time dependent fields, the connection between magnetic and electric fields and the role of special theory of relativity in understanding the electromagnetic phenomena is also explained. The main objectives of the course are:

- To explain the various techniques for solving the boundary value problems.
- Investigate various consequences of Maxwell's equations. Viz. Gauge invariance, conservation laws and boundary conditions of electromagnetic fields at an interface.
- Application of Maxwell's equations for the study of propagation of electromagnetic waves in various media.
- To understand and develop the theory of wave guides and electromagnetic radiation phenomena.
- To look at the close relationship between electromagnetic phenomena and special theory of relativity.

Course Outcome:

CO	CO Statement	CL
CO1	Will get familiarized with the various boundary value problems and learn different techniques for its solutions (Module 1)	Understand
CO2	The introduction of conservation laws and investigation of the propagation of electromagnetic waves in various media leads to a clear understanding and applications Maxwell's equations (Module 2)	Understand
CO3	Will learn some of the other important consequences of Maxwell's equations by studying: 1. Electromagnetic wave propagation in wave guides and conducting media. 2. The electromagnetic radiation phenomena (Module 3).	Understand
CO4	Will understand the important concepts involved in special theory of relativity and its intimate connection to the electrodynamics phenomena (Module 4).	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	2	1	1
CO2	1	2	2	1	1
CO3	1	2	2	1	1
CO4	1	2	2	1	1

Module I

Review of vector calculus, Multipole expansion- electrostatic multipole moments - energy of a charge distribution in an external field. Boundary value problems, Introduction to Green's function, formal solution with Green's functions, electrostatic potential energy. Method of images- point charge near a grounded conducting sphere-point charge near a charged insulated conducting sphere - conducting sphere in an uniform electric field. Laplace equation in spherical polar coordinates- boundary value problem with azimuthal symmetry.

Module II

Maxwell's equations. Vector and scalar potentials - gauge transformations - Lorentz gauge, Coulomb gauge. Poynting's theorem and conservation of energy and momentum, complex Poynting vector. Boundary conditions for the electric and magnetic fields at an interface - Plane electromagnetic wave in a non-conducting medium, linear and circular polarization, reflection and refraction at a dielectric interface, polarization by reflection and total internal reflection.

Module III

Waves in conducting or dissipative medium-skin depth. Cylindrical cavities and wave guides, metallic wave guides, modes in a rectangular wave guide, resonant cavities. Green's function for wave equation. Simple radiating systems- fields and radiation of a localized oscillating source - electric dipole field and radiation, magnetic dipole and electric- quadrupole fields.

Module IV

Special theory of relativity - Postulates of relativity, Lorentz transformations, four vectors, addition of velocities, four velocity, relativistic momentum and energy, mathematical properties of space-time, matrix representation of Lorentz transformation. Dynamics of relativistic particles. Lagrangian and Hamiltonian of relativistic charged particle, motion in a uniform static electric and magnetic fields, magnetism as a relativistic phenomenon, transformation of the electromagnetic field, electromagnetic field tensor.

Text Books:

1. J. D. Jackson, Electrodynamics, 3rd Edition, Wiley (2009).
2. Introduction to Electrodynamics, D. J. Griffiths, 4th Edition, Cambridge University Press (2017).

Reference Books:

1. The Classical theory of fields - L D Landau and E M Lifshitz Pergamom Press Ltd (1971)
2. Electrodynamics - M. Chaichian, I. Merches, D Radu and A. Tureanu, Springer Verlag, (2016)
3. Classical Electrodynamics - W Greiner , Springer Verlag , New York (1998)

24-807-0703: Quantum Mechanics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

The primary aim of the course is to provide an introduction to the mathematical formulation of Quantum Mechanics along with its physical principles. In addition, this course discusses some of the important time-independent 1D and 3D problems in Quantum Mechanics. The general objectives of course are:

- To formulate Quantum Mechanics using abstract mathematical structure of linear vector spaces.
- Describe the postulates of Quantum Mechanics and discuss the concepts of state, observables and time evolution in Quantum Mechanics.
- Discuss Schrodinger and Heisenberg formulations of Quantum Mechanics.
- Discuss various 1-dimensional and 3-dimensional time independent problems in quantum mechanics

Course Outcome:

CO	CO Statement	CL
CO1	Students will get an understanding of linear vector spaces which are fundamental to quantum mechanics . They will also learn concepts and properties of inner-product, basis, linear operators (in particular Hermitian operators) (Module I)	Understand
CO2	A thorough understanding of the postulates of quantum mechanics and other key concepts is obtained through the 2 nd module. The connection between classical and quantum physics is also elaborated in this module. (Module II)	Understand
CO3	Students will solve various 1-dimensional time independent problems in quantum physics. This will help them to formulate such problems and understand the general properties of solutions (Module III).	Understand, Apply
CO4	The student will learn to solve various 3-dimensional time independent problems in Quantum Mechanics. Study of angular momentum and atomic structure will be crucial to understand other subjects like spectroscopy. Quantum Theory of scattering is introduced (Module IV).	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	2	0	0
CO2	2	2	2	0	1
CO3	2	2	2	0	0
CO4	2	3	2	2	0

Module I

Linear Vector Spaces: de Broglie's hypothesis: matter waves and experimental confirmation; Linear vector spaces: inner product, Hilbert space, Wave Functions; Linear operators: Hermitian operators, Projection operators, Commutator algebra, Unitary operators, Eigenvalues and Eigen vectors of a Hermitian operator; Basis: Representation in discrete bases, Matrix representation of kets, bras, and operators, Change of bases and unitary transformations, Matrix representation of the eigenvalue problem, Representation in position bases.

Module II

Postulates of Quantum Mechanics: Postulates of Quantum Mechanics: State of a System, Probability Density, Superposition Principle, Observables as Operators, Position and Momentum operators, Position and Momentum representation of state vector, Connecting the position and momentum representations, Measurement in quantum mechanics, Expectation values, Commuting operators and Uncertainty relations; Time evolution of the state: Time-independent potentials and Stationary States, Time evolution operator, infinitesimal and finite Unitary Transformations; Conservation of probability; Time evolution of expectation values: Ehrenfest theorem; Poisson's brackets and commutators; Matrix and Wave mechanics.

Module III

Time independent 1D problems: Discrete, continuous and mixed spectrum; symmetric potentials and parity; Infinite square well potential; Symmetric potential well; Finite square well potential: Scattering and bound state solutions; Free particle; Delta function potential; Harmonic oscillator.

Module IV

Time independent 3D problems: Free particle in 3-dimensions: spherically symmetric solution; Particle in a 3D box; Schrodinger equation in presence of central Potential; Orbital angular momentum: eigen values and eigen functions of of L^2 and L_z ; Hydrogen Atom. [Text Book: Nourdine Zettili]. Scattering Theory: Kinematics, Scattering Cross Section, Green's function and Scattering am- plitude. Born approximation and its validity, Born series [Text Book: Mathews and Venkate- san].

Text Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009.
2. Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill, 2010.

Reference Books:

1. David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004.
2. J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley,1994
3. R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994
4. V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985

Semester VIII

24-807-0801: Statistical Physics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

This course introduces students to the fundamental principles of equilibrium statistical physics. The focus is on developing a formalism to derive macroscopic or emergent quantities of various physical systems. The course is a very relevant one for students at a Master's level, as the formalism introduced underpins all of material science and other branches where one is interested in the collective behavior of a system.

Course Outcome:

Upon completion of this course, a student should be able to -

CO	CO Statement	CL
CO1	Differentiate between systems in equilibrium and out of equilibrium	Understand, Analyse
CO2	Demonstrate an understanding of the terminology, concepts and principles of describing equilibrium properties of physical systems	Understand
CO3	For a given ideal system, derive various macroscopic quantities - either using a classical or a quantum setting - using the principles learned	Apply
CO4	Derive the macroscopic properties of ideal quantum gases	Apply
CO5	Develop a basic understanding of various aspects of the statistical physics of systems with interaction between its constituent components	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	2	1	1
CO2	1	2	2	1	1
CO3	1	2	2	1	1
CO4	1	2	2	1	0
CO5	1	2	2	1	0

Module I

Features of macroscopic systems: Concept of equilibrium, Irreversibility and approach to equilibrium, Basic probability concepts: Statistical ensembles, Mean values and fluctuations, Statistical description of a system of particles, Micro and macro states, The microcanonical ensemble.

Module II

Thermal Interaction, Distribution of energy between macroscopic systems, Systems in contact with a heat reservoir, Canonical ensemble and the Boltzmann distribution, Partition function and Free energy, Paramagnetism, Ideal gas in canonical ensemble - mean energy and mean pressure, harmonic oscillator, Grand Canonical ensemble.

Module III

Canonical distribution in the classical approximation: Phase space of classical systems, Ideal gas, entropy of mixing and Gibbs paradox, Maxwell velocity distribution, harmonic oscillator, The equipartition theorem and its applications, Liouville's theorem.

Module IV

Statistical physics of ideal quantum gases: Ideal Fermi gas at zero and non-zero temperatures, Fermi-Dirac and Bose-Einstein integrals, Ideal Bose gas - Bose-Einstein condensation, Density operator. Interacting systems: 1D Ising model, Mean field approach, Phase transitions, Critical point and critical exponents, Universality, Renormalization group approach (Qualitative ideas).

Text Books:

1. Statistical Physics, Berkeley Physics Course, Volume 3, F. Reif, Tata- McGraw-Hill (2008).
2. Principles of equilibrium statistical mechanics, D. Chowdhury and D. Stauffer, Wiley (2000).

Reference Books:

1. An introduction to thermal physics, Daniel V Schroeder, Pearson Education (2007).
2. Statistical Mechanics, K. Huang, Wiley India (2008).
3. Statistical Physics, Landau and Lifshitz, Elsevier (2005).

24-807-0802: Mathematical Physics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

This course introduces different mathematical tools used in physics to the students. The course aims to prepare the students for understanding and applying various mathematical formalisms. The material covered in this course is very important for students as the mathematical techniques introduced find applications in every branch of physics and other quantitative sciences.

Course Outcome:

CO	CO Statement	CL
CO1	Demonstrate an understanding of the meaning of gradient, divergence and curl. Work with them in different coordinate systems, and solve problems involving scalar and vector fields	Understand, Apply
CO2	Demonstrate an understanding of basic tensor analysis	Understand
CO3	Solve problems involving calculus of functions of a complex variable	Apply
CO4	Solve a second order linear differential equation	Apply
CO5	Solve important partial differential equations such as Laplace equation, wave equation and Poisson equation by the method of separation of variables	Apply
CO6	Solve algebraic & differential equations, and calculate definite integrals numerically	Apply
CO7	Solve basic problems in probability and demonstrate a deep understanding of the Binomial, Poisson and Gaussian probability distributions	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	3	1	0	1
CO2	1	3	1	0	1
CO3	1	3	1	0	1
CO4	1	3	1	0	1
CO5	1	3	1	0	1
CO6	1	3	1	0	1
CO7	1	3	1	0	1

Module I

Review of vector calculus. Orthogonal curvilinear coordinates, cylindrical and spherical polar coordinates. Vector integration and integral theorems. Tensor analysis: Contravariant and covariant vectors, Basic operations with tensors, Quotient law, The line element and metric tensor.

Module II

Complex numbers, functions of a complex variable, mapping, branch lines and Riemann surface. Calculus of functions of a complex variable, elementary functions of z. Complex integration. Series representations of analytic functions. Integration by the method of residues, evaluation of real definite integrals.

Module III

Solution of linear second order differential equations. The Euler linear equation. Solutions in power series - Frobenius method, Bessel's equation. Simultaneous equations. Partial differential equations, Solutions of Laplace's and wave equation, solution of Poisson's equation - Green's function method, Laplace and Fourier Transform methods.

Module IV

Numerical methods: Interpolation. finding roots of equations, graphical methods, method of linear interpolation, Newton's method. Numerical integration, the rectangular rule, The trapezoidal rule, Simpson's rule. Numerical solutions of differential equations, Euler's method, Runge-Kutta method, equations of higher order, system of equations. Least-squares fit.
Probability theory - definitions and sample space. Random variables and probability distributions. Calculating expectation and variance. The Binomial, Poisson and Gaussian distributions.

Text Books:

1. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).

2. Mathematical Methods for Physicists Paperback (7th Edition), Arfken, Elsevier (2012).

Reference Books:

1. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2001).

Semester IX

24-807-0901: Nuclear and Particle Physics

Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to develop an understanding of advanced nuclear physics with the underlying quantum mechanical principles. Also, the students can get the idea of different types of nuclear radiation detectors and their properties. The course provides the details of different elementary particles an its properties. In short, the course provides a good platform to carry forward the studies to higher levels.

Course Outcomes

After completing this course the students should be able to

CO	CO Statement	CL
CO1	Describe the basic properties of the nuclear force. (Module 1)	Understand
CO2	Explain the nucleon-nucleon scattering and its underlying principles. (Module 1)	Understand, Evaluate
CO3	Review the different nuclear models and nuclear reactions. (Module 2)	Understand, Evaluate
CO4	Discuss nuclear fission and its applications. (Module 2)	Understand, Apply
CO5	Classify different nuclear radiations and radiation detectors. (Module 3)	Evaluate
CO6	Explain the properties of the nucleus	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	2	0	1
CO2	3	3	2	2	1
CO3	3	3	2	1	1
CO4	3	2	3	2	0
CO5	3	2	2	3	0
CO6	3	2	3	2	0

Module I

Nuclear properties: Review of basic concepts, Nuclear radius, shape, spin, parity, Magnetic and electric moments, Nuclear binding energy. Nuclear two body problem, The deuteron, simple theory, spin dependence, tensor force, nucleon-nucleon scattering, partial wave analysis of n-p scattering, determination of phase shift, singlet and triplet potential, effective range theory, low energy p-p scattering.

Module II

Nuclear models, semi empirical mass formula, stability of nucleus, shell model, spin orbit potential, valance nucleons, Nilsson Model, Collective Model, Rotational and Vibration States.

Nuclear reactions, conservation laws, energetic, compound nuclear reactions, direct reaction, resonant reaction, nuclear fission, energy in fission, controlled fission reactions, fission reactors.

Module III

Nuclear decays: barrier penetration and alpha decay, beta decay, simple theory of beta decay, Kurie plot, parity violation in beta decay, gamma decay, multipole moments and selection rules.
Detection of nuclear radiation: Interaction of radiation with matters, gas-filled counters scintillation detectors, semiconductor detectors, energy and timing measurement.

Module IV

Meson Physics, properties of pi-mesons, decay modes, meson resonance, strange meson and baryons, CP violation in K decay.
Particle interaction and families, symmetries and conservation laws, quark model, coloured quarks and gluons, reactions and decays in the quark model, c, b and t quarks, quark dynamics.

Text Books:

1. Introductory Nuclear Physics (3rd Edition), Kenneth S. Krane, Wiley (1987).
2. The particle hunters (2nd Revised Edition), Yuval Ne'eman & Yoram Kirsh, Cambridge University Press (1996).

Reference Books:

1. Introduction to Nuclear Physics (1st Edition), Harald A. Enge, Addison Wesley (1996).
2. Concepts of Nuclear Physics, B. L. Cohen, McGraw-Hill Inc., US (1971).
3. Nuclear Physics: Theory and Experiment, R. R. Roy and B.P. Nigam, Newagepublishers (1996).
4. Theoretical Nuclear Physics, J. M. Blatt and V. F. Weisskopf, Springer-Verlag New York (1979).
5. An Introduction to Nuclear Physics (2nd Edition), S. B. Patel, New Age International (2011)
6. Introduction to Elementary Particles (2nd Revised Edition), David Griffiths, Wiley VCH (2008).

24-807-0902: Solid State Physics

Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to make the learner understand the physics of solids, which form the basic foundation for the study of other fields inside and outside the condensed matter physics. The course provides a clear picture about the development of the subject and how the knowledge about the solids and their properties used to change our society.

Course Outcomes

CO	CO Statement	CL
CO1	Understand the semiclassical and quantum mechanical models for explaining various electronic, thermal properties of solids (Module 1)	Understand, Evaluate
CO2	Develop ideas on crystal structure, reciprocal space and diffraction techniques (Module 2)	Understand, Evaluate
CO3	Summarize band theory of solids and the developments of semiconductor physics (Module 3)	Understand, Evaluate
CO4	Explore magnetic properties of solids, mean-field theories and basics of superconductivity (Module 4)	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	0	0
CO2	3	1	2	0	0
CO3	3	1	2	0	0
CO4	3	1	2	0	0

Module I

Solids Without Considering Microscopic Structure: The Early Days of Solid State , Specific Heat of Solids - Einstein's Calculation-Debye's Calculation-Periodic (Born-von Karman) Boundary Conditions - Debye's Calculation Following Planck - Debye's "Interpolation" - Shortcomings of the Debye Theory - Electrons in Metals: Drude Theory - Electrons in an Electric Field - Electrons in Electric and Magnetic Fields - Thermal Transport - Sommerfeld (Free Electron) Theory - Basic Fermi-Dirac Statistics - Electronic Heat Capacity - Magnetic Spin Susceptibility (Pauli Paramagnetism) - Shortcomings of the Free Electron Model.

Module II

Vibrations of a One-Dimensional Mono-atomic Chain - Phonons-Crystal Momentum , Vibrations of a One-Dimensional Diatomic Chain - The Reciprocal Lattice in Three Dimensions - General Brillouin Zone Construction - Electronic and Vibrational Waves in Crystals in Three Dimensions - Wave Scattering by Crystals - Equivalence of Laue and Bragg conditions - Scattering Amplitudes - Systematic

Absences - Geometric Interpretation of Selection Rules - Methods of Scattering Experiments - Powder Diffraction - Scattering in Liquids and Amorphous Solids.

Module III

Electrons in Solids - Electrons in a Periodic Potential - Kronig-Penny Model- Bloch's Theorem- Nearly Free Electron Model - Tight Binding Model - Energy Bands in One Dimension - Energy Bands in Two and Three Dimensions - Introduction to Electrons Filling Bands - Multiple Bands - Band-Structure Picture of Metals and Insulators - Optical Properties of Insulators and Semiconductors - Direct and Indirect Transitions - Optical Properties of Metals - Optical Effects of Impurities - Electrons and Holes - Doping - Impurity States - Statistical Mechanics of Semiconductors -Band Structure Engineering - Designing Band Gaps - Non-Homogeneous Band Gaps.

Module IV

Magnetism and Mean Field Theories - Hund's Rules - Coupling of Electrons in Atoms to an External Field - Free Spin (Curie or Langevin) Paramagnetism - Larmor Diamagnetism - (Spontaneous) Magnetic Order - Ferromagnets - Antiferromagnets - Ferrimagnets - Macroscopic Effects in Ferromagnets: Domains - Domain Wall Structure and the Bloch/ Neel Wall - Hysteresis in Ferromagnets.
Superconductors - Type-I and Type-II superconductors - Meissner effect - BCS theory (qualitative) - High temperature superconductors - applications - Josephson effect.

Text Books:

1. Solid state physics, Ashcroft, Neil W. and Mermin, N., Brooks/Cole (1976).
2. The Oxford solid state basics, Simon, Steven, Oxford University Press (2004).
3. Introduction to Solid State Physics (8th Edition), Charles Kittel, Wiley (2004).

Reference Books:

1. Solid State Physics, Dekker, A. J., Macmillan (2000).
2. Solid State Physics: Structure and Properties of Materials, M.A. Wahab, 2005, Narosa Publishers.
3. Elementary solid state physics principles and applications, M Ali Omar, 2013, Pearson Education Inc.
4. Elements of x-ray diffraction (3rd edition), Cullity, B. D. and Stock, Stuart H., Prentice Hall (2001).

Elective Courses

Level 300 Electives

10: Astrophysics

Course Code: 10
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To study in detail the elements of Astrophysics, with an aim to develop the taste of research in the field.

Course Outcome

CO	CO Statement	CL
CO1	Acquire a thorough understanding of the basic concepts like magnitudes, color, H-R diagram etc.	Understand
CO2	Understand the theory of hydrostatic equilibrium in stars	Understand
CO3	Get a clear idea about the energy production in stars	Understand
CO4	Get a clear knowledge about the evolution of the main sequence stars	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	0	3	0	2
CO2	2	2	2	0	1
CO3	2	2	2	0	1
CO4	2	1	2	0	1

Module I

Magnitudes: Apparent and Absolute stellar magnitudes, distance modulus, Bolometric and radiometric magnitudes, Color - index, Color temperature, effective temperature, Brightness temperature,luminosities of stars. Equatorial, ecliptic and galactic system of coordinates. Apparent and Mean solar time and their relations. Classification of stars, H-D classification, Hertzsprung-Russel (H-R) diagram.

Module II

Fundamental Equations: Equation of mass distribution. Equation of hydrostatic equilibrium. Equation of energy transport by radiative and convective processes. Equation of thermal equilibrium. Equation of state. Stellar opacity. Stellar energy sources.

Module III

Stellar Models : The overall problem and boundary conditions. Russell Voigt theorem. Dimensional discussions of mass luminosity law. Polytropic configurations. Homology transformations.

Module IV

Stellar Evolution: Jean's criterion for gravitational contraction and its difficulties. Pre-main sequence contraction under radiative and convective equilibrium. Evolution in the main sequence. Growth of isothermal core and subsequent development. Ages of galactic and globular clusters.

Text Books :

1. Textbook of astronomy an astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.
2. Astrophysics - Stars and Galaxies, K. D. Abhyankar, University Press, 2001.

Reference Books :

1. M.Schwarzschild:Stellar Evolution
2. S.Chandrasekhar:Stellar Structure
3. Theoritical Astrophysics (Vols.I,II,III) - T. Padmanabhan (CUP)
4. Menzel,Bhatnagar and Sen:Stellar Interiors.
5. Black Holes, White Dwarfs and Neutron Stars - S.L.Shapiro and S.A.Teukolsky (John Wiley, 1983)
6. Cox and Guili:Principles of Stellar Interiors - Vol.I and II.
7. R.Bowers and T. Deeming:Astrophysics (John and Barlett.Boston)

11: Biophysics

Course Code: 11
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of this course is to introduce the interdisciplinary subject biophysics. This course also aims to give insights to the students on applications of physics in biosystems.

Course Outcomes

CO	CO Statement	CL
CO1	Fundamental understanding of biophysics	Understand, Analyse
CO2	Fundamental understanding of allied areas of biophysics	Understand
CO3	Fundamental areas of crystal structure determination of proteins	Understand
CO4	To get an insight on Protein folding	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	2	0
CO2	3	3	2	2	0
CO3	1	3	3	3	0
CO4	2	2	3	3	0

Module I

Fundamental building blocks of biological systems-Molecules essential for life- Water-proteins- lipids-carbohydrates-cholestrol-Nucleic acid-living state interactions-forces and molecular bonds-electric and thermal interactions-polarisations and induced dipoles-Casimir interactions- (Qualitative treatment) heat transfer in biomaterials-heat transfer mechanisms-heat equation-heat transfer through a living cell-Joule heating tissue (Qualitative treatment).

Module II

Living state thermodynamics-thermodynamic equilibrium-First and second law of thermodynamics-measures of entropy-free expansion of gas-physics of many particle systems- Boltzmann factor in biology-DNA stretching- Brownian motion-Ficks laws of diffusion-Ficks law for growing bacterial cultures(Qualitative treatment)-Sedimentation of cell cultures.

Module III

Nerve impulses-Neurotransmitters and synapses-Passive and active transports in dendrites- Mechanical properties of biomaterials (Qualitative treatment)-Youngs, shear modulus and Poisson ratio-electrical stresses in bilological membranes-Mechanical effects of microgravity during space flight, fundamentals of biomagnetic field sources- fundamentals Passive electrical properties of living cells.

Module IV

Light absorption in biomolecules-Bioimpedence-Time harmonic current flow- Dielctric spectroscopy-Deybe relaxation model-Cole equation-Fundamentals of protein folding, basic techniques for protein folding, protein crystallization, Vapor diffusion- Sitting drop method- Hanging drop method- Basics of structure determination of proteins with X-ray crystallography- sample handling techniques.

Text Books:

1. Introductory biophysics perspectives on the living state J.Claycomb, J.Quoc P.Tran, Jones & Bartlet Publishers.
2. Biophysics; N. Arumugam, V. Kumaresan, Saras publication; SBN : 9789384826673.
3. Biological Physics; Philip Nelson; W. H. Freeman & Company ; 2013.
4. Protein Folding; Charis Ghelis; Academic Press;1982.
5. Preparation and Analysis of Protein Crystals; McPherson, A. 1982, John Wiley & Sons.
6. Terese M. Bergfor's, Protein Crystallization Techniques, Strategies and Tips, International University Line, 1999.

12: Complex Networks

Course Code: 12
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15
Prerequisites: None

Course Objectives

This course aims to introduce to the students the emerging area of complex networks. The course is a very relevant one in this era of complex systems and gives the students a flavor of interdisciplinary approaches to problem solving.

Course Outcomes

CO	CO Statement	CL
CO1	Demonstrate an understanding of the terminology, concepts and principles involved in the study of complex networks	Understand
CO2	Identify problems that can be treated using the tools of complex networks	Understand, Analyse
CO3	Calculate various properties of a complex network related to its local structure	Apply
CO4	Calculate various properties of a complex network related to its global structure	Apply
CO5	Demonstrate an understanding of various models of complex networks and their properties and applications	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1	2	0
CO2	3	2	1	2	0
CO3	3	3	1	2	0
CO4	3	3	1	2	0
CO5	3	2	1	2	0

Module I

Introduction,Examples of networks, Mathematics of networks: Networks and their representation, The adjacency matrix, Networks: Weighted, Directed, Bipartite and Planar, Trees, Hypergraphs. Degree, Path, Components. Independent paths, connectivity, cut sets, The graph Laplacian, random walks.

Module II

Measures and Metrics: Degree centrality, Eigenvector centrality, Katz centrality, Page-rank, Hubs and authorities, Closeness centrality, Betweenness, Signed edges and structural balance, Similarity, Homophily and assortative mixing.

Module III

Large scale structure of networks: Components, Shortest paths and the small world effect, Degree distributions, Power-laws and scale free networks, Clustering coefficients.

Module IV

Network models, Erdos-Renyi random graph: Definition and properties. The configuration model: Definition and properties, Models of network formation.

Text Books:

1. Networks: An Introduction, M.E.J. Newman, Oxford University Press (2010).

Reference Books:

1. Network science, Albert Barabasi, Cambridge University Press (2016).

13: Elementary Astronomy

Course Code: 13
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

This course enable the students learn the salient advancements in the field of Astronomy.

Course Outcome

CO	CO Statement	CL
CO1	Get knowledge about the celestial sphere and its various properties and uses.	Understand
CO2	Get good knowledge regarding the theories of solar system, planets - their formation and properties	Understand
CO3	Get a reasonable knowledge about the formation of stars, and objects like white dwarf, black hole etc.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	1	2	0
CO2	1	0	1	2	0
CO3	1	0	1	2	0

Module I

Celestial Sphere and Time : Constellations. The celestial sphere. Equatorial, ecliptic system of co-ordinates. Seasons, Sidereal, Apparent and Mean solar time. Calendar. Julian date. Stellar Distances and Magnitudes : Distance scale in astronomy. Determination of distances to planets and stars. Magnitude scale. Atmospheric extinction. Absolute magnitudes and distance modulus. Colour index.

Module II

Theories of formation of the Solar System, The Sun: Photosphere, chromosphere and corona of the Sun. Sun spots and magnetic fields on the sun. Solar activity, solar wind.
Planets and their Satellites : Surface features, atmospheres and magnetic fields of Earth, Moon and Planets. Satellites and rings of planets. Asteroids, Meteors, Meteorites and Comets.

Module III

Stars : Basics of Star formation & Evolution. The HR diagram. Pre-main sequence contraction, main sequence stage and formation of super dense objects - White dwarfs, Neutron stars & Pulsars. Black holes.

Module IV

The Milky Way Galaxy & Galaxies beyond : Structure of the Milky Way Galaxy Galactic and globular clusters. Inter Stellar Matter, Position of our Sun and its motion around the galactic centre. Rotation of the Galaxy and its mass.

Extragalactic Systems : Hubble's classification of galaxies and clusters of galaxies. Galaxy interactions, Elements of Astrobiology.
Introduction to Cosmology : The expanding universe. Big Bang and Steady State models of the universe. Dark matter.

Text books:

1. H. Karttunen, P Kroger, H Oja, M Poutanen & K. J. Donner editors. Fundamental Astronomy, 5^{th} Edition, Springer-Verlag (2007).
2. Baidyanath Basu: Introduction to Astrophysics, PHI, 2nd ed. (2013)

References :

1. W.M.Smart: Foundations of Astronomy, Longmans (1965)
2. Frank H. Shu: The Physical Universe-An Introduction to Astronomy, Univ Science Books (1981)
3. K D Abhyankar: Astrophysics of the Solar System, Universities Press (1999)
4. Horneck and Rettberg: Complete Course in Astrobiology, Wiley (2009)
5. Introduction to cosmology, J V Narlikar, Cambridge University Press; 3 edition (2002)

14: Fundamentals of Photovoltaics

Course Code: 14
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of the course is to develop in-depth understanding of the physics of solar cells and various photovoltaic technologies (PV) and their applications to harness solar energy to electricity. The course will cover the basic semiconductor physics. The course will give an insight in the fabrication of the solar cells in laboratory and industrial scale, module fabrication and power generation using PV in off grid and grid connected systems.

Course Outcomes

CO	CO Statement	CL
CO1	Explain the working principle of solar cells	Understand
CO2	Understand PV based electricity generation	Understand
CO3	Differentiate the manufacturing and performance differences between different c- Si wafer technologies and between c-Si and thin film PV technologies	Understand, Analyse
CO4	Identify the critical losses and loss mechanisms in c-Si solar cells	Understand, Analyse
CO5	Calculate the power and energy produced by a solar module	Apply
CO6	Explain the differences and design aspects of off-grid and on-grid PV systems.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	1	2	0
CO2	1	0	1	2	0
CO3	1	0	1	2	0
CO4	1	0	1	2	0
CO5	1	0	1	2	0
CO6	1	0	1	2	0

Module I

Basic Semiconductor Physics: Fundamental Properties of Semiconductors - Crystalline structure - Band model - Doping - Carrier concentration in equilibrium - Light absorption -Generation and recombination of electron and hole pairs: Band gap to band gap processes - Shockley-Read-Hall recombination - Auger recombination - Carrier transport - Minority carrier diffusion - Semiconductor junctions: p-n homojunctions - ideal diode equation - p-n heterojunctions - Metal-semiconductor junctions.

Module II

Solar Cell fundamentals: p-n junction under illumination - Solar Cell Parameters - Spectral response - the equivalent circuit - parasitic resistance effects -temperature effect - p-i-n solar cells - Losses and Efficiency Limits: The thermodynamic limit - the Schokley-Quiesser limit - other losses - design rules for solar cells - tandem solar cells First Generation technology: Crystalline Silicon Solar Cells - Physics of c-Si Solar cells - Sand to silicon - Silicon to wafer - wafer manufacturing - Design and manufacturing of Al-BSF solar cell - Passivation concepts

Module III

High efficiency concepts in c-Si Solar cells: PERL and PERC cells - interdigitated back contacts - TOPCon - Heterojunction solar cells Second generation technology: Thin film solar cells - merits and demerits -Transparent conducting oxides - the III-V PV technology - thin film Si technology - Chalcogenide solar cells - Organic photovoltaics - Hybrid organic-inorganic solar cells Third generation concepts: Multi junction solar cells - Spectral conversion - Multi- exciton generation - Intermediate band solar cells - Hot carrier solar cells.

Module IV

Module manufacturing: Interconnection of cells - series and parallel connections- silicon module production - PV systems: Standalone systems – grid connected systems - hybrid systems - micro grids - smart grids - specific applications- Solar cell and module measurement techniques.

Text Books:

1. K. Mertens, Photovoltaics: Fundamentals, Technology and Practice, John Wiley & Sons Ltd (2014)
2. A. Smets, K. Jager, O. Isabella, R. V. Swaaij, M. Zeman, Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems, UIT Cambridge Ltd. (2016).
3. D. A. Neamen and D. Biswas, Semiconductor Physics and Devices

Reference Books:

1. Handbook of Photovoltaic Science and Engineering 2nd Ed. , A. Luque, S. Hegedus (editors), John Wiley & Sons Ltd (2011)
2. S.R. Wenham, M. Green, M.E. Watt, R. Corkish, A. Sproul, Applied Photovoltaics, 2nd Edition (2009)
3. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and applications, 3rd Edition, PHI Learning Pvt. Ltd. (2019).
4. Jenny Nelson, The Physics of Solar Cells, Imperial College Press (2003).
5. Peter Wurfel, Physics of solar cells: from principles to advanced concepts, 2nd Edition, Wiley-VCH (2009).
6. SM Sze and Kwok K Ng, Physics of semiconductor devices, third edition, John Wiley & Sons (2007)
7. R.F. Pierret, Semiconductor Device Fundamentals

15: Measurements and Optical Instrumentation

Course Code: 15
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course is designed so as to enable a student to understand different types of errors and noise occurred in Physical measurement system. It also aims to familiarize the student about optical detectors and spectroscopic instruments.

Course Outcomes

CO	CO Statement	CL
CO1	Know the techniques to reduce errors in measurements and reduction of noises in experimental data	Understand, Apply
CO2	Get knowledge about different types of optical detectors and the design concept of optical spectrometer	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	1	2	0
CO2	1	2	1	2	0

Module I

Measurement, The Result of a Measurement, Sources of Uncertainty and Experimental Error, Systematic Error, Random Error, Definition of the Uncertainty, The Analysis of Repeated Measurements, The Mathematical Description of Data Distribution Functions, Derivation and properties of the Data Distribution Functions, Propagation of Error, Analysis of Data, Instrumentation and system design, experiment design, Multi-parameter Experiments.

Module II

Transducers, Transducer Characteristics, selection of an Instrumentation Transducer, The Transducer as an Electrical Element, Modeling External Circuit Components, Signal to noise considerations, Fluctuations and Noise in Measurement Systems, Noise in the Frequency Domain, Sources of Noise, Signal to Noise, a signal to Noise and Experimental Design, Frequency and Bandwidth Considerations, Boxcar integration.

Module III

Optical Measurements and the Electromagnetic Spectrum, Detectors, Thermal detectors, Photoconductive, piezoelectric and photo emissive detectors, photodiodes, Avalanche Photodiode phototransistors, applications, optical couplers, materials used to fabricate LEDs and lasers design of LED for optical communication, response times of LEDs, LED drive circuitry.

Module IV

Interferometry: Interference effect, radiometry, types of interference phenomenon and its application, Michelson's interferometer and its application refractometer, Rayleigh's interferometers, Spectroscopic instrumentation, Visible and Infrared Spectroscopy, Spectrometer Design, Refraction and Diffraction, Lenses and Refractive Optics, Dispersive Elements, spectrographs and monochromators, spectrophotometers, calorimeters Spectrometer Design.

Text Books:

1. Measurement, Instrumentation and experiment design in Physics and Engineering Michael Sayer and Abhai Mansingh prentice-Hall India.

2. J.Wilson & J F B Hawkes, Opto Electronics: An Introduction, Prentice Hall of India, (2011), 3rd ed.

3. Rajpal, S.Sirohi , Wave Optics and its Application, (2001), 1st ed.

4. A Yariv , Optical Electronics/C.B.S. Collage Publishing, New York, (1985).

5. Pollock ,Fundamentals of OPTOELECTRONICS, (1994).

16: Nondestructive Measurement Techniques and Applications

Course Code: 16
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

Obtain knowledge about fundamental principles different types of non-destructive testing and characterization methods used to determine the structure and composition of materials for practical applications.

Course Outcomes

CO	CO Statement	CL
CO1	Fundamental of Non-destructive measurement techniques	Understand
CO2	Instrumental application of Non-destructive measurement techniques	Apply
CO3	Application of Non-destructive measurement techniques	Apply
CO4	Industrial applications of Non-destructive measurement techniques	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2	3	0
CO2	2	3	3	3	0
CO2	2	3	3	3	0
CO2	1	3	3	3	1

Module I

Magnetism-Basic Definitions- Principle of MPT - Magnetizing Techniques -Magnitization using a magnet - Magnetization using an electromagnet - Contact current flow method. Eddy Current - Principles - Instrumentation for ECT -Techniques - High sensitivity techniques - Inspection of heat exchanger tubings by single frequency EC system - Multifrequency ECT - High frequency ECT - Pulsed ECT - 3D or phased array ECT - Inspection of ferromagnetic materials - Sensitivity - Applications - Limitations - Standards.

Module II

Radiography - Basic principle - Electromagnetic Radiation Sources -X-ray source - Production of X-rays - High energy X-ray source - Gamma ray sources - Properties of X- and gamma rays - Radiation Attenuation in the specimen - Effect of Radiation in film - Film ionization -Inherent unsharpness-Radiographic Imaging - Geometric factors - Radiographic film - Intensifying screens -Film density - Radiographic sensitivity - Penetrameter - Determining radiographic exposure -Inspection Techniques -Single wall single image technique - Double wall penetration technique .
Microwave methods-introduction, microwave radiation, microwave instrumentation, microwave measurements. Raman spectroscopy for NDT applications. Raman spectroscopy as nondestructive tool. Instrumentation.

Module III

Ultrasonic Testing - Basic properties of Sound Beam - Sound waves - Velocity of ultrasonic waves - Acoustic pressure - Behaviour of ultrasonic waves - Ultrasonic Transducers - Characteristics of ultrasonic beam - Attenuation - Inspection methods - Normal incident pulse- echo inspection - Normal incident through transmission testing - Angle beam pulse-echo testing - Criteria for probe selection - Flaw sensitivity - Beam divergence - Penetration and resolution - Techniques for Normal beam inspection - Fatigue cracks -Inclusions, slag, porosity, and large grain structure - Thickness measurement-corrosion detection - Intergranular cracks-hydrogen attack-Techniques for Angle beam inspection- Flow characterization techniques - Ultrasonic flaw detection equipment - Modes of display - A-scan - B-scan - C-scan - Immersion testing - Applications of ultrasonic testing -Advantages - Limitations – Standards.

Module IV

Visual Examination Basic Principle - The Eye - Defects which can be detected by unaided visual inspection-Optical Aids Used for Visual Inspection-Microscope Borescope - Endoscope - Flexible fibre-optic Borescope (Flexiscope) - Telescope –The concept of Holographic imaging – The inline hologram- The off axis hologram-Fourier hologram- Nondestructive applicationof holography- Holographic interferometry-Real time holographic interferometry-Double-Exposure holographic interferometry-Sandwitch holograms- Holographic interferometry in an industrial environment- Holographic strain analysis.

Reference Books :

1. Electrical and Magnetic Methods of Non -Destructive Testing, Jack Blitz,Champan & Hall,2-6 Boundary Row,London SE1 8HN.
2. Practical Nondestructive Testing, Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Publishing House New Delhi
3. Optical Electronics, Ajoy Ghatak and K.Thygarajan,Cambridge University Press India Pvt.Ltd.
4. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
5. P.Hariharan, Optical Holography-Principles techniques and applications. Cmbridge Studies in Modern Optics.

17: Non-linear Dynamics and Chaos

Course Code: 17
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To make the students understand the field of non-linear dynamics.

Course Outcomes

CO	CO Statement	CL
CO1	Understanding the basic of non-linearity in physical systems.	Understand
CO2	Understanding the discrete dynamical systems, logistic map and associated things.	Understand
CO3	Familiarise the concepts like Lyapunov exponents and its application in detecting chaos in systems.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Linear and nonlinear forces- Working definition of nonlinearity. Linear oscillators- free, damped and forced oscillators- Nonlinear oscillations and resonance.
Dynamical systems as systems of first order ordinary differential equations. Equilibrium points and their classification (two-dimension). Limit cycles, attractors, dissipative and conservative systems.

Module II

Simple bifurcations in dissipative systems. Discrete dynamical systems. Logistic map. Equilibrium points and stability. Periodic orbits. Period-doubling bifurcations. Onset of chaos. Lyapunov exponents. Bifurcation diagram. Strange attractors in Henon map. Quasiperiodic and intermittency route to chaos. Period-doubling bifurcations and chaos in Duffing oscillator and Lorenz equations.

Module III Canonical perturbation theory- problem of small divisors. Statement and discussion of KAM theorem. Surface of section. Henon-Heiles Hamiltonian(numerical results). Area-preserving maps. Poincare-Birkhoff theorem. Homoclinic points.

Module IV

Lyapunov exponents-numerical computation-one-dimensional maps and continuous time systems. Power spectrum. Autocorrelations.
Fractal sets-examples. Fractal dimension-box counting. Correlation dimension. Criteria for chaotic motion.

Text Books:

1. Nonlinear Dynamics, M.Lakshmanan and S.Rajasekar, Springer, (2003)
2. Chaos and Integrability in Nonlinear dynamics, M.Tabor, John Wiley, (1989)

Reference Books:

1. Chaos- an introduction to nonlinear dynamics, J. Alligood, T. Sauer and J.Yorke, Springer, (1997)
2. Chaos and Nonlinear Dynamics, R.C. Hilborn, Oxford University Press, (1994)
3. Deterministic Chaos, H.G.Schuster, Wiley-VCH, 3rd edition (1995)

18: Physics of Nanomaterials

Course Code: 18
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to develop an understanding of nanostructured materials and their various synthesis methods and characterization techniques. After completing the course, the students will be able to differentiate between bulk materials and nanomaterials, understand the optical, electrical, mechanical, and magnetic properties specific to nanomaterials. Additionally, the students become familiar with various top-down and bottom-up approaches for the synthesis of nanomaterials, as well as characterization tools for calculating particle size.

Course Outcomes

CO	CO Statement	CL
CO1	Understand the fundamental differences between nanostructured materials and bulk materials, and classification of nanomaterial based on dimension.	Understand
CO2	Classify 0D,1D,2D, and 3D materials and its optical, electrical, mechanical and magnetic properties	Understand, Analyse
CO3	Differentiate between different Bottom-up and Top-down methods used for nanomaterials synthesis with examples from literature.	Analyse
CO4	Assess different characterization tools used for understanding the size and distribution of nanomaterials	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	0	3	3	2
CO2	3	0	3	3	2
CO3	2	0	3	3	1
CO4	3	1	3	3	1

Module I

Introduction to nanoscience and technology (brief ideas), concept of electrons, holes, and excitons, low dimensional structures, quantum well, quantum wire and quantum dots, fullerenes, carbon nanotubes, structure of CNT, vibrational, mechanical and optical properties of CNT, applications of carbon nanotube.

Module II

Size effects on the optical, electrical, mechanical and magnetic properties, weak excitonic confinement and strong excitonic confinement, blue shift, Giant magnetoresistance (GMR) and Colossal magnetoresistance (CMR).

Module III

Synthesis of nanostructured materials, Bottom-up and Top-down processes, method of making 1- D and 2-D nanomaterials, high energy ball milling, co-precipitation technique, sol gel synthesis, solvothermal methods-control of grain size chemical vapor deposition (CVD), physical vapor deposition (PVD), Lithography.

Module IV

Characterization of nanomaterials, preliminary ideas about the operation and characterization of nano materials using scanning electron microscope (SEM), transmission electron microscope (TEM), scanning tunneling microscope (STM), atomic force microscope (AFM) and x-ray diffraction (XRD).

Text Books:

1. Michael F. Ashby, Paulo J. Ferreira, Daniel L. Schodek, Nanomaterials, Nanotechnologies and design, an introduction for engineers and architects, Elsevier (2009).

2. K.K Chattopadhyay, and A.N Banerjee, Introduction to nanoscience and nanotechnology, PHI Learning Private Limited, New Delhi.

3. B S Murty, P Shankar, Baldev Raj, B B Rath, and B B Rath, Textbook of Nanoscience and Nanotechnology, springer.

4. S.V. Gaponenko, Optical properties of semiconducting nanocrystals, Cambridge University Press (1997).

5. David B. Williams, and C. Barry Carter, Transmission Electron Microscopy: A textbook for materials science, second edition, Springer.

6. B. D. Cullity, and S. R. Stock, Elements of X-Ray diffraction, Springer, (2001).

Reference Books:

1. A. K. Bandhyopadhyay, Nanomaterials, New Age International Publishers (2007).

2. Bieter K. Schroder, Semiconductor material and device characterization, Wiley - Inter-science publication (1993)

3. A I Gusev and A A Remphal, Nanocrystalline materials, Cambridge International Science Publishing

4. Hari Singh Nalwla, Nanostructured materials and nanotechnology Vol. I, II, III, IV, V, VI, VII,VIII, IX (2002)

5. K L Chopra and Inderjeet Kaur, Thin Film Device Applications, Plennum Press (1983)

6. J H Davis, Physics of low dimensional structures Cambridge (1998).

19: Principles of Biomedical Instruments

Course Code: 19
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of this course is to understand the underlying physics of the medical imaging systems and to give an overview of major modern diagnostic techniques.

Course Outcomes

CO	CO Statement	CL
CO1	Get a good understanding, on biomedical instruments	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1

Module I

Flame photometers, Introduction to Spectro photometers,Beer lambert law,Colorimeters, Blood gas analyzers, Principles and techniques of sterilization–Autoclave, Sterrad. Chromatography – Gas and liquid Chromatographs – Principle and applications. Mass spectroscopy, flow cytometry–Principles and applications. Electrophoresis – Principles and applications.

Module II

X-rays:Principle and production of X-rays, Interaction of X rays with matters, Transfer characteristics of screen, Film and image intensifier systems, Properties of X-ray films and screens, Characteristics of Imaging system by image modulation transfer functions, Radiography:Various components of Radiography systems – Exposure switching and control of exposure time – Types of timer circuits, Filament circuit and KV– mA controls – HT units – X-ray tubes for various medical applications – fixed anode, rotating anode, X-ray tubes for specialized applications – collimators

Module III

Medical ultrasound: Physics of ultrasonic waves, Interactions with body matter, Generation and detection, Single element transducer, Linear and sector scanning Transducer arrays, Different modes of display, Modes of transmission of ultrasound, Colour Doppler, Ultrasonic diagnosis in abdomen, Breast, Heart, Chest, Eye, Kidney, Skull, Pulsatile motion, Pregnant and Non-Pregnant uterus. Ultrasound pulse echo imaging system, Design of scan converters, Design of frame grabbers, 2D scanners.

Module IV

Magnetic Resonance Imaging:Principles of image formation– MRI instrumentation-magnets Gradient system – RF coils receiver system, Pulse sequence– Image acquisition and reconstruction techniques, Application of MRI, Fundamentals of magnetocardiography and magnetoencephalography

Text Books:

Text Books :

1. Fundamental Physics of radiology,W.J. Meredith & J.B. Massey, Varghese Publishing House, Bombay, 1992.
2. The Physics of Diagnostic Ultrasound, Peter Fish, John Wiley & Sons, England, 1990. 4.
3. Ultrasound Physics & Instrumentation,D.L. Hykes, W.R. Hedrick & D.E. Starchman, Churchill Livingstone, Melbourne, 1985.

Reference Books :

1. Principles of Applied Biomedical Instrumentation,L.A.Geddes & L.E.Baker, Wiley
2. Handbook of Analytical Instruments, Khandpur R S, Tata McGraw Hill,1989
   India Pvt.Ltd, Third Edition, 1989.
3. Radiographic Imaging,D.N. & M.O. Chesney, CBS Publishers, 1990.
4. The Physics of Medical Imaging, S. Webb, IOP Publishing Ltd., 1988.

20: Light Sources and Detectors

Course Code: 20
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

This course aims to introduce students to the basic characteristics and working principle of various light sources and detectors in the UV-VIS-IR regimes.

Course Outcomes

CO	CO Statement	CL
CO1	Explain the difference between natural and artificial sources of light.	Understand
CO2	Explain the basic characteristics and working principle of various photon sources and detectors in ultraviolet-visible-infrared regions of the electromagnetic spectrum.	Understand
CO3	Demonstrate the safety procedures to be taken while setting up experiments with advanced optical sources and detectors.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Natural and Artificial Sources of Light, Characteristics of Light Sources, UV-VIS- IR Light Sources, Type of Optical Sources- Incandescent Lamp, Discharge Lamps-Low Pressure, High Pressure, and High Intensity Discharge Lamps, Semiconductor Diode-Light Emitting Diode (LED), Supercontinuum Sources.

Module II

Laser Fundamentals, Gas Lasers, Solid State Lasers, Semiconductor Laser Diodes, Safety Standards and Hazard Classifications, Laser Applications.

Module III

Detector Characteristics Quantum Efficiency, Response Time, Spectral Response. Types of Photoeffects-Photovoltaic Effect, Photoemissive Effect, and Photoconductive effect. Optical Detectors - UV, VIS, NIR, & IR Ranges.

Module IV

Types of Photon Detectors: Photodiodes, Photomultiplier Tube (PMT), Photodiode Array (PDA), Light Dependent Resistor (LDR), Charge-Coupled Device (CCD), Time Gated Detectors-Intensified Charged Coupled Device (ICCD).

Text Books:

1. Introduction to Solid-State Lighting - Zukauskas, Shur, Gaska, Wiley (2002)
2. Laser Fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
3. E. L. Dereniak, and D. G. Crowe, Optical Radiation Detectors, (Wiley Series in Pure and Applied Optics), Wiley, New York (1984).

References

1. Kingston, Robert H., Detection of Optical and Infrared Radiation, (Springer Series in Optical Sciences, Vol.10), Springer Verlag, New York (1978).
2. Chandra Roychoudhuri (Editor), Fundamentals of Photonics, SPIE (2008)
3. Bahaa E. A. Saleh Malvin Carl Teich, Fundamentals of Photonics, John Wiley & Sons, Inc. (1991)

21: Science to Data Science: An Introductory Course with Python applications

Course Code: 21
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to provide the big picture of data science/analytics with specific applications that enable a science graduate to choose a career involving statistical analysis and modeling of data.

Course Outcomes

CO	CO Statement	CL
CO1	Learn elements of probability theory with commonly used probability distributions.	Understand
CO2	Build foundations of statistical inference and parameter estimation	Understand
CO3	Learn advanced topics of Bayesian inference and Monte Carlo methods.	Apply, Analyse
CO4	Learn techniques and tools for analyzing modeling data (including machine learning).	Understand, apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1
CO4	3	1	3	3	1

Module I

Elements of probability theory: conditional probability, Bayes theorem. Random variables: continuous and discrete case, probability distribution functions, expectation values. Common probability distributions and applications: binomial, Poisson, Gaussian, power law distributions, etc.; Multivariate Gaussian distributions.

Module II

Statistical inference: General Concepts - population, sample, statistic, estimator, bias, sampling distribution - chi2, Student-t distributions Hypothesis testing: Null and alternate hypothesis, test statistic, significance level, p-value Point estimation - method of moments, maximum likelihood method, least square and Chi-square fitting, Confidence intervals and limits - goodness of fit.

Module III

Bayesian inference and their applications - Bayesian parameter estimation. Stochastic Processes: Continuous and Point Processes - White noise, Poisson Process, Markov Process, etc. Time series analysis - basic concepts, auto, and cross-correlations; Monte Carlo Methods - Uniformly distributed random numbers, the acceptance-rejection method, applications, Markov Chain Monte Carlo methods, Metropolis-Hastings Algorithm.

Module IV

Data visualization with Python.
Regression analysis - least square linear regression, non-linear regression.
Introduction to Machine Learning: Elements of neural networks, deep learning Applications.

Reference Books:

1. Probability and Statistics: The Science of Uncertainty (Second Edition), Michael J. Evans and Jeffrey S. Rosenthal, W. H. Freeman Publishers, 2010.

2. Applied Statistics and Probability for Beginners, , D. C. Montgomery, G. C. Runger, John Wiley & Sons, 2024.

3. Stochastic Processes in Physics and Chemistry (third edition), N. G. Van Kampen, Elsevier Science B, 2007.

4. Machine Learning Specialization https://www.coursera.org/specializations/machine-learning-introduction.

Level 400 Electives

40: Advanced Electronics

Course Code: 40
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

Advanced level knowledge in electronics is essential to understand the working of computers, telecommunication systems, sophisticated analytical instruments, and other electronic appliances in our everyday life. After completion of this course, the students will be able to design different digital and analog electronic circuits for specific applications like register, counter, analog to digital converter, integrator, differentiator, comparator, waveform generators, microcontroller etc.

Course Outcomes

CO	CO Statement	CL
CO1	Understand the primary applications of the operational amplifier as an adder, subtractor, differentiator, integrator, comparator, and waveform generator etc. (Module 1)	Understand
CO2	Explain the working of different combinational and sequential logic circuits and its design using universal-NAND gates. (Module 2)	Understand
CO3	Explain the architecture of 8085 Microprocessor, instructions, and its working. Write assembly language program for 8085 Microprocessor (Module 3)	Understand, Apply
CO4	Understand the basics of microcontroller and programming it using open source development board Arduino (Module 4).	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	0	1	3	3	0
CO2	0	1	3	3	0
CO3	0	1	3	3	0
CO4	0	1	3	3	0

Module I

Ideal amplifier - operational amplifier - the basic operational amplifier, differential amplifier and its transfer characteristics, frequency response of operational amplifiers, adder, subtractor, Op-amp as differentiators, integrators, applications of differentiators and integrators, Solution of differential equations, general ideas about analog computation and simulation, other applications of Op-amps, filters, comparators, sample and hold circuits, waveform generators.

Module II

Combinational systems - Synthesis of Boolean functions, Boolean algebra, Universal gate - NAND, Integrated NAND circuit, Arithmetic circuits, Adder, Subtractor, BCD Addition, 2's complementary technique, Sequential systems - Flip flops-RS, JK, JK-MS, D-FF, Register, Buffer register, serial and parallel registers, Tristate switches, Tristate buffer registers, Bus organization in computers, Counters, Synchronous and Asynchronous counters, Ripple counters, Ring counter, Timing diagram, Fundamentals of D/A conversion,-Accuracy and resolution -ADC/DAC chips, Flash Converters.

Module III

Microprocessor architecture , memory, input/output, 8085 MPU, Instructions and timings, instruction classification, instruction format, instruction timing and operation status, Programming the 8085, data transfer instructions, arithmetic operations, logic operations, branch operations, examples of assembly language programs.

Module IV

Microcontroller basics, introduction to Arduino: open-source electronics prototyping, Basic ideas of Arduino, familiarize the Arduino board, IDE in PC/ laptop for Arduino programming(Sketch), data types, variables and constants, operators, control statements, loops, functions, string, serial communication, digital and analog input/output, getting input from sensors, practical applications.

Text Books:

1. Robert G. Irvine, Operational Amplifier Characteristics and Applications, 2nd Edition, Prentice Hall, New Jersey (1987).
2. John Ryder, Electronic Fundamentals and Applications (5th Edition), Prentice Hall, New Delhi, (1983).
3. A. Anand Kumar, Fundamentals of Digital Circuits (4-th Edition), Eastern Economy Edition (2019)
4. Ramesh Gaonkar, Microprocessor Architecture, Programming and Applications, Wiley Eastern Limited, New Delhi (1992).
5. Michael Margolis , Arduino Cookbook, O'Reilly Media (2011); Massimo Banzi, Getting Started with Arduino, O'Reilly Media (2009).

Reference Books:

1. Ramakant A. Gayakwad, Op-Amps and Linear Integrated Circuits (4 th Edition) Pearson Paperback (2015).
2. Milman and Halkias, Integrated Electronics, Mc. Graw Hill, (1983)
3. John Wakerly, Digital Design: Principles and Practices (4th Ed.), Prentice Hall (2005).
4. D. C. Green, Digital Electronics (5th Ed.), Pearson Education Ltd., (2005).
5. Giovanni Organtini, Arduino as a tool for physics experiments, J. Phys.: Conf. Ser. 1076 012026 (2018)
6. Web: https://www.arduino.cc/en/Guide/HomePage

41: Advanced Raman Spectroscopy

Course Code: 41
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15
Prerequisites: None

Course Objectives

Raman spectroscopy is one of the important spectroscopic techniques which has wide variety of applications different fields of science and technology. The objective of this course is to understand the advanced applications of Raman spectroscopy including structure determination of micro and nano materials. This course also aims to give insjghts in to different Raman process which has applications in industry, material science, medicine and forensic science etc.

Course Outcomes

After completion of this course, the students will have good fundamental understanding, instrumental aspects, and analysis of materials using Raman spectroscopy.

CO	CO Statement	CL
CO1	Fundamental understanding of Raman spectroscopy	Understand
CO2	Working principle of Raman instrumentation	Understand
CO3	Advanced applications of Raman spectroscopy	Understand, Apply
CO4	Characterisation of materials using Raman spectroscopy	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3	3	0
CO2	2	2	3	3	0
CO3	1	1	3	3	0
CO4	0	1	3	3	0

Module I

Raman effect, classical theory of Raman effect, quantum mechanical treatment of Raman effect, Hyper Raman effect, Classical treatment of Hyper Raman effect, Experimental techniques for hyper Raman effect, Photoacoustic Raman scattering, Surface-Enhanced Raman Spectroscopy (SERS), Principle of SERS, Enhanceemnt mechanism, Electromagnetic enhancement mechanism, Chemical enhancement, Surface selection rules, SERS substrates, metal films, metallic nanoparticles, Applications-biomolecules, fundamentals of SERS based detection of virus, in medicine, forensic science, pharmaceuticals.

Module II

Raman spectrometer, Major Components, Excitation Sources - Lasers, Sample Illumination, Wavelength Selectors, Detection, FT Raman, Detection, Photon Counting, photodiode array, CCD, Instrument Calibration, Sampling Techniques, Fluorescence Problems, Raman Difference Spectroscopy, Miniature Raman Spectrometers, FT Raman spectrometer, Single crystal Raman spectra, Raman Microscopy, Fibre optical Raman spectrometer, Resonance Raman Spectroscopy.

Module III

Special techniques, High pressure Raman spectroscopy, Temperature and pressure induced phase transitions and its sample handling techniques and instrumentation. Raman microscopy, applications, Raman spectroeelctrochemistry- Applications, proton conduction in solids-Raman studies, time resolved Raman Spectroscopy- applications, matrix isolation Raman spectroscopy- applications, 2D correlation Raman Spectroscopy- applications, Raman Imaging, Spectromerty- applications, Industrial Applications, Environmental applications.

Module IV

Stimulated Raman scattering, inverse Raman scattering, CARS (Coherent antistokes Raman scattering), Analysis of Raman data, Compounds having inorganic functional groups, molecular symmetry, fundamental modes of vibration, Molecules of type XY 2 , XY 3 , XY 4 , Sulphates, Phosphates, Carbonates, Iodates, Tungstates, Bromates etc. Analysis of Raman spectra of carbon rich compounds, carbon nano tubes, graphite, graphine G, D and 2D bands, Analysis of oxide nano structures, Analysis of Organic compounds, hydrogen bonds.

Text Books:

1. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
2. Introductory Raman spectroscopy Second Edition, J R Ferraro, K.Nakamoto, C.W.Brown, Academic press, Elsevier.

Suggested Reading:

1. Resonance Raman Spectroscopy; Roman S. Czernuszewicz & Marzena B. Zaczek; Encyclopedia of Inorganic and Bioinorganic Chemistry, Online©2011 John Wiley & Sons, Ltd. DOI: 10.1002/9781119951438.eibc0303

42: Advanced Quantum Mechanics

Course Code: 42
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to provide an introduction to advanced level topics in quantum mechanics. These include quantum theory of angular momentum, approximate methods for solving time dependent and time independent problems and an introduction to relativistic and multi-particle quantum mechanics. The general objectives are:

- To formulate a quantum theory of the total and the spin angular momentum of quantum particles.
- Formulate the time independent perturbation theory to find energy eigen values and eigen functions of problems that are not exactly solvable.
- Introduce WKB approximation and variational method for time-independent potentials.
- Introduce time-dependent perturbation theory to solve problems where potential is dependent on time.
- Formulate relativistic quantum mechanics
- Introduce the multi-particle quantum systems and their wave-functions. Discuss indis- tinguishably of identical particles.

Course Outcomes

CO	CO Statement	CL
CO1	Students will get a complete understanding of the total and the spin angular momenta of fundamental particles. They will also understand how angular momenta will add in a combined system. This is crucial to understand spectroscopy (Module I)	Understand
CO2	Students will be able to apply approximate methods like the perturbation theory, WKB method and variational method to solve time-independent problems that are not exactly solvable (Module II)	Understand
CO3	Perturbative approach to solve time-dependent problems will be understood. Various applications like Fermi's Golden rule, semi-classical theory of radiation will also be introduced (Module III)	Understand, Apply
CO4	Student will understand to formulate a relativistic theory of quantum mechanics and also multi particle quantum mechanics (Module IV)	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	2	2	0
CO2	2	3	2	0	1
CO3	2	3	2	0	0
CO4	2	2	2	2	1

Module I

Quantum Theory of Angular Momentum: Review of Orbital angular momentum; General theory of angular momentum: Commutation relations, eigenvalues, Matrix representation of angular momentum; Spin angular momentum: Pauli spin matrices and their properties, Two component wave function, Pauli's equation; Addition of Angular momentum and Clebsch-Gordan coefficients.

Module II

Time Independent Perturbation theory: Time-independent perturbation theory: Non degenerate perturbation theory, The Stark effect, Degenerate perturbation theory: Spin Orbit Coupling, Fine structure; Variational method; WKB method, Bound states for potential wells, Transmission probability for tunnelling through a potential barrier.

Module III

Time Dependent Perturbation theory Schrodinger and Heisenberg Pictures of Quantum Mechanics; The interaction Picture and Time- dependent perturbation theory: Transition probability; Constant perturbation; Harmonic perturbation; Adiabatic and Sudden approximations. Interaction of atoms with radiation: Transition rates for absorption and stimulated emission of radiation, Dipole approximation, Electric dipole selection rules.

Module IV

Relativistic and Multi Particle Quantum Mechanics Klein-Gordon equation: Free particle solutions, Probability density. Dirac equation: Dirac matrices, Plane wave solutions, Spin of Dirac particle, Negative energy solutions.[Mathews and Venkateshan]
Many Particle Systems: Interchange symmetry; Systems of distinguishable non-interacting particle. Systems of identical particles: Exchange degeneracy, Symmetrization postulate; Constructing symmetric and anti-symmetric wave functions, Pauli's exclusion principle [Nourdine Zettili].

Text Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009
2. Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill, 2010.
3. Walter Greiner, Relativistic Quantum Mechanics Wave Equations, 3rd Edition, Springer, 2000 (Module IV)

Reference Books:

1. J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley,1994.
2. Walter Greiner, Relativistic Quantum Mechanics Wave Equations, 3rd Edition, Springer, 2000 (Module IV)
3. R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994
4. David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004

5. V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985 (Module IV)

43: Applied Vibrational Spectroscopy

Course Code: 43
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course is designed so as to enable a student to understand the fundamentals and applications of vibrational spectroscopic techniques –Raman and infrared spectroscopic techniques. It also aims to familiarize the student about spectroscopic instruments and sample handling techniques.

Course Outcome

CO	CO Statement	CL
CO1	know the techniques to measure Raman and IR spectra of the sample organic and inorganic compounds	Understand, Apply
CO2	get knowledge about the analysis of Raman and Infrared data of the samples	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	2	2	0
CO2	2	1	2	2	0

Module I

Infrared spectroscopy- Fundamentals of Infrared spectroscopy- Infrared spectra preliminary- Infrared selection rules-Vibrations of polyatomic molecules-Normal vibrations of CO_2 and H_2O molecules-Dipole moment change in CO_2 molecule-Nomenclature of Internal modes- Fermi resonance-Hydrogen bonding-Normal modes of vibration in crystal-Solid state effects-Interpretation of vibrational spectra-group frequencies- Applications-Identification of molecular Constituents-Elucidation of molecular structure-Biological applications-Isotope effect.

Module II

Fundamentals of Raman spectroscopy-Classical and quantum theory-Molecular types-Planar molecules-pyramidal molecules-tetrahedral molecules-octahedral molecules-Rule of mutual exclusion principle-Internal modes of vibration-Polarization of Raman scattered light-Single crystal Raman spectra-Structure determination using Raman and IR spectroscopy- Raman investigations of phase transitions-Proton conduction in solids Raman study-Industrial applications-Resonance Raman scattering-Surface enhanced Raman scattering-Chemical enhancement –Electromagnetic enhancement-Substrates for SERS measurement.

Module III

Raman instrumentation-General idea on laser sources for Raman measurements-Components of Raman spectrometer-Modern spectrometers-Fibre coupled Raman spectrometer-FT Raman spectrometer-Raman microscopy- Raman sample handling techniques- High pressure Raman measurement system-Temperature dependent Raman measurement system- Raman measurement system with electric field

IR instrumentation-IR sources-Components of IR spectrometer -FTIR spectroscopy-Interferometer arrangement- IR sample handling techniques.

Module IV

Analysis of Raman spectra and IR spectra-basic idea of factor group analysis-general idea on softwares for the computation of vibrational spectra- Vibrational spectral anaylysis of Inorganic compouds containing water- Sulphate- phosphate -bromate- carbonate- complexes of sulfate, carbonate, and related ligands-Organic compounds - Carbon nanotubes- graphite- Oxide nanomaterials- Identification of hydrogen bonded ssytem- Analysis of historical monuments-Forensic samples-cyano and nitrile complexes.

Text Books:

1. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
2. Infrared and Raman Spectra of Inorganic and Coordination Compounds: Part A: Theory and Applications in Inorganic Chemistry, Sixth Edition; K.Nakamoto; 2009 John Wiley & Sons, Inc.
3. Infrared and Raman Spectra of Inorganic and Coordination Compounds: Part B Applications in Coordination, Organometallic, and Bioinorganic Chemistry, Sixth Edition; K.Nakamoto; 2009 John Wiley & Sons, Inc.

44: Atomic and Molecular Spectroscopy

Course Code: 44
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

Atomic and molecular spectroscopy provides a foundational understanding of quantum mechanics, which is essential for comprehending the behaviour of matter at the atomic and molecular levels. This knowledge is fundamental in physics, chemistry, and related disciplines. The objective of this course is to understand the origin of the quantized nature of atomic and molecular energy levels in a system and its applications in material characterization. The interaction between electromagnetic radiation and matter, commonly studied through spectroscopy, holds immense importance across various scientific disciplines and technological applications. This course also aims to provide detailed working principles of different laser systems, which have numerous applications in industry, material science, medicine, and telecommunications.

Course Outcomes

CO	CO Statement	CL
CO1	Describe the electronic state of atoms in terms of quantum numbers, the complexity of atomic spectra due to spin-orbit coupling, and the interpretation of term symbols. (Module 1)	Understand
CO2	Explain how atoms absorb and emit light and how this process can be affected by magnetic and electric fields. (Module 1).	Understand
CO3	Explain the contributions of transitions between rotational, vibrational and electronic states to the spectra of diatomic molecules. (Module 2)	Understand, Apply
CO4	Describe how IR and Raman spectroscopic techniques are used in molecular structure determination. (Module 3)	Apply, Analyse
CO5	Distinguish different spectroscopic techniques (absorption, fluorescence, Raman, NMR, and EPR). (Module 3)	Apply, Analyse
CO6	Write the rate equations of three-level and four-level laser systems and describe the working principle of specific laser systems. (Module 4)	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	2	1
CO2	3	1	2	2	1
CO3	3	1	1	2	1
CO4	3	1	1	1	1
CO5	3	1	2	1	1
CO6	3	1	3	3	1

Module I

Quantum states of electrons in atoms - Pauli's exclusion principle, calculation of spin-orbit interaction energy in one electron systems, fine structure of spectral lines in hydrogen and alkali atoms. Equivalent and non-equivalent electrons, two electron systems, interaction energy in LS and j j couplings, spectra of helium and alkaline earth elements. Normal and anomalous Zeeman effects, Stark effect, Paschen-Back effect (all in one electron system only). Hyperfine structure of spectral lines - calculation in one electron systems. Line broadening mechanisms - line shape functions for Natural, Collisional, and Doppler broadenings.

Module II

Types of molecules, rotational spectra of diatomic molecules as rigid rotor, intensity of rotational lines, The effect of isotopic substitution, energy levels and spectrum of non-rigid rotor, techniques and instrumentation for microwave spectroscopy. The vibrating diatomic molecule - simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator - CO molecule. Interaction of rotation and vibrations, the vibrations of polyatomic molecules and their symmetry, the influence of rotation on the spectra of linear molecules - Electronic spectra of diatomic molecules - Born-Oppenheimer approximation, vibrational coarse structure - progressions. Intensity of vibrational transitions – the Franck- Condon principle. Dissociation energy and dissociation products. Rotational fine structure of electronic-vibrational transitions - the Fortrat diagram. Predissociation.

Module III

Raman effect - classical theory, elementary quantum theory, pure rotational Raman spectra - linear molecules, vibrational Raman spectra polarization of light and Raman effect, techniques and instrumentation of Raman and IR spectroscopy, structure determination by IR and Raman spectroscopy- simple examples, fundamentals of SERS.
Nuclear and electron spin - interaction with applied magnetic field, population of energy levels Larmor procession, NMR: NMR of hydrogen nuclei - chemical shift, techniques and instrumentation for NMR spectroscopy, medical applications of NMR - ESR spectroscopy - g factor - fine and hyperfine structure, double resonance, Basic idea of Mossbauer Spectroscopy- Recoilless emission and absorption.

Module IV

Einstein's Coefficients, Laser Fundamentals and Fabrication- Active Medium, Pumping Sources, and Optical Resonator, Phenomenon of Population Inversion, Characteristics of Laser Light, Three and Four Level Lasers - Rate Equations - Pumping Threshold, Specific Laser Systems – Ruby Laser, Nd:YAG Laser, Ti:Sapphire Laser, He-Ne Laser, Argon ion Laser, CO 2 Laser, Excimer Laser, Semiconductor Diode Lasers, Laser Applications in Industry, Material Science, Medicine, and Telecommunications.

Text Books:

1. Introduction to Atomic Spectra, H. E. White, McGraw-Hill Inc., US (1934).
2. Fundamentals for Molecular Spectroscopy, 4th Ed., C. N. Banwell and E. M. McCash, McGraw Hill Education (2017).
3. Laser fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
4. Lasers Theory and Applications, 2nd Ed., K. Thayagarajan and A.K Ghatak, Springer (2011).
5. Molecular structure and Spectroscopy (2nd Edition), G. Aruldhas, Prentice Hall of India (2007).

Reference Books:

1. Spectroscopy Vol. I, II and III, B.P. Straughan and S.Walker, Chapman and Hall (1976).
2. Introduction to Molecular Spectroscopy, G. M. Barrow, McGraw-Hill Inc.,US (1962).
3. The Physics of Atoms and Quanta (4th ed.), H. Haken and Hans C. Wolf, Springer-Verlag (1994).
4. Laser Physics, Peter W. Milonni and Joseph H. Eberly, Wiley-Blackwell (2010).
5. Optical Electronics, A.K.Gahtak and K. Thayagarajan, Cambridge University press (1989).

45: Crystal Growth

Course Code: 45
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of this course to provide information on the important aspects of crystals growth. This course also aims to give insights to the students on growing techniques crystals with different methods.

Course Outcomes

CO	CO Statement	CL
CO1	Acquire good fundamental understanding on crystal growth	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1	2	0

Module I

Supersaturation and supercooling – nucleation concept – Kinds of nucleation - Homogeneous nucleation - Equilibrium stability and metastable state -Classical theory of nucleation - Gibbs-Thomson equation –Kinetic theory of nucleation - Statistical theory of nucleation - Free energy of formation of nucleus considering translation, vibration and rotation energies, Theories of crystal growth - Surface energy theory - Diffusion theory - Adsorption layer theory -Volmer theory -Bravais theory - Kossel theory.

Module II

Melt Growth Techniques -Crystal Pulling-Bridgman Method-Skull Melting Methods-Zone Melting-Verneuil Process -Kyropolous method - Czochralski method-Zone melting method - Growth of crystal from flux - Slow cooling method - Temperature difference method – High pressure method - Solvent evaporation method - Top seeded solution growth - Growth of crystals from vapour phase - Physical vapour deposition - Chemical vapour transport.

Module III

Solution Growth Techniques -General Aspects-Low-Temperature Methods-High- Temperature Methods-Growth of crystals from solutions - solvents and solutions - solubility - preparation of a solution -saturation and supersaturation - Measurement of supersaturation - Expression for supersaturation -Low temperature solution growth - Crystal growth by hydrothermal method– Crystal growth by solvo-hydrothermal method- Slow cooling method - Mason-jar method - Evaporation method -Temperature gradient method - Crystal growth in gels - Experimental methods -Chemical reaction method - Reduction method method - Growth of biologically important crystals.

Module IV

Crystallization of hydroxy apatite - Protein crystallization techniques - Hanging Drops-Sitting Drops-Sandwich Drops-Reverse Vapor Diffusion- pH Gradient Vapour Diffusion-Practical Tips for Vapuor Diffusion –Dialysis-Batch Techniques –Micro batch –Protein Samples- Precipitants- Buffers and pH

–Temperature-Crystallization Strategies-A Flexible Sparse Matrix Screen-An Alternative to Sparse-Matrix Screens-Reverse Screen- Imperial College Grid Screen- Seeding-Macro seeding-bio-crystallization, protein crystallization and characterization of biological crystals.

Text Books:

1. J.C. Brice, Crystal growth processes, John Wiley and sons, New York, 1986.
2. P.Santhana Raghavan and P.Ramasamy, Crystal Growth Processes and Methods, KRU Publications, Kumbakonam (2000).
3. A. Laudise, The Growth of single crystals. Prentice Hall, 1970.
4. B.Pamplin, Crystal Growth. Volume 16, Pergamon Press.1973.
5. F.F. Abraham, Homogenous nucleation theory, Advances in Theoretical Chemistry, Academic Press, New York, 1974.
6. R.F. Strickland, Kinetics and Mechanism of Crystallization, Academic Press, New York, 1968.
7. Sujata V. Bhat, Biomaterials, Narosa Publising House, New Delhi,2002
8. A.Ducruix and R.Giege, Crystallization of Nucleic Acids and Proteins A Practical Approach, Oxford University Press, England, 1992
9. Terese M. Bergfor's, Protein Crystallization Techniques, Strategies and Tips, International University Line, 1999.

46: Laser and Nonlinear Optics

Course Code: 46
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims at developing creative skills among students by understanding the principles of high-power lasers and applications. Topics include revising the basic principles of lasers, laser cavities, properties of Gaussian beams and imaging. The latter part of the course focuses on high power pulsed lasers from Q-switched nanosecond lasers to femto-second lasers and amplifiers.

Course Outcomes

CO	CO Statement	CL
CO1	Analyse the propagation of Gaussian beams	Understand, Analyse
CO2	Apply the principles of phase contrast imaging	Apply
CO3	Illustrate pulse shortening mechanisms and chirped pulse amplification	Understand, Apply
CO4	Elaborate high power laser interaction with material	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	2	1	0
CO2	3	1	2	1	0
CO3	3	0	2	0	1
CO4	2	2	3	0	2

Module I

Review of Radiation Laws (Stefan Boltzmann, Wien Displacement, Planks) and basics of lasers (Population Inversion - Stimulated emission - Einstein Coefficients) - Laser , Ruby Laser.

Module II

Optical Resonant Cavities , Longitudinal and Transverse modes , Properties of Gaussian laser beams , Spatial frequencies , Abbels theory of image formation , Spatial Filtering phase contrast Imaging.

Module III

Pulsed high power lasers , Q switching , Methods of producing Q switching , Mode locking , Methods of producing mode locking , Pulse shortening by self phase modulation, Group velocity dispersion, gratings or prisms , femto-second lasers , basic ideas of chirped pulse amplification and regenerative amplifiers.

Module IV

Nonlinear Optics , Nonlinear Wave equation , Optical rectification , Harmonic Generation , Phase matching , Third Harmonic generation , Parametric oscillator , B integral - self focusing , Two photon absorption.

Text Books:

1. Hecht, E and A R Ganesan, Optics 4th Ed., Pearson (2019).
2. Silfvast, W T, Laser Fundamentals 2nd Ed., Cambridge University Press (2008)
3. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press (2003).

References

1. Ajoy Ghatak, Optics 5th Ed., McGraw Hill.
2. Bahaa E . A. Saleh and Malvin Carl Teich , Fundamentals of Photonics 2nd Ed., Wiley (1991)
3. Laud, B.B. - Lasers and Nonlinear Optics, New Age International (P) Limited (1991)

47: Modern Optics

Course Code: 47
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The first part of the course (Modules 1 & 2) aims to expose learners to the concepts of polarization, coherence, interference, and diffraction and to apply these for the design of optical devices. Topics include polarization of light, coherence, and interference, Fraunhofer (far-filed) and Fresnel (near-field) diffraction, holography, and light modulators. The latter part of the course aims to develop creative skills among students by understanding the principles of high-power lasers and applications. Topics include revising the basic principles of lasers, laser cavities, properties of Gaussian beams and imaging. The course focuses also on high power pulsed lasers from Q-switched nanosecond lasers through to femto-second lasers and amplifiers.

Course Outcomes

CO	CO Statement	CL
CO1	Illustrate and apply principles of optical systems	Understand, Apply
CO2	Apply concepts for the design of high and anti-reflection coatings, interference filters etc.	Apply
CO3	Employ the theory of interference and diffraction for the development of devices like zone plates, holographic recording and re-construction.	Apply
CO4	Illustrate pulse shortening mechanisms and pulse amplification in modern lasers.	Analyse
CO5	Explain linear to nonlinear transformation in laser material interactions	Understand
CO6	Embrace lifelong learning and scientific research.	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	2	1	1
CO2	3	1	2	0	1
CO3	3	1	2	0	1
CO4	3	0	3	0	1
CO5	3	1	2	0	1
CO6	0	0	1	0	2

Module I

Polarisation: Nature of polarized light – linear, partial, elliptical and circular polarizations- Polarizers and Retarders - Jones Vectors of linearly, elliptically and circularly polarized light - Jones matrices for optical components. Induced optical effects – electro-optic modulators – Pockels effect - longitudinal and transverse electro optic modulators - Kerr effect - Magneto-optic effect, acousto-optic effect – Raman Nath and Bragg-type modulators.

Module II

Coherence: Spatial and temporal coherence-Visibility-Mutual coherence function - Degree of coherence – Temporal and spatial coherence. Interference: General considerations - Condition for interference - Wave front splitting- and Amplitude splitting interferometers – Fringes of equal inclination – Fringes of equal thickness – Michelson, Mach Zehnder and Sagnac interferometers - Fabry Perot interferometer – Fabry-perot spectroscopy - Applications of single and multilayer films - Anti-reflection coatings – Multilayer periodic systems - Interference filters.

Module III

Diffraction: Kirchhoff's theorem - Fresnel-Kirchhoff Formula – Babinets principle – Fraunhofer and Fresnel diffraction - Fraunhofer diffraction patterns for single, double slits, rectangular aperture, and circular aperture – Optical resolution – Diffraction gratings - Fresnel diffraction pattern – Fresnel Zones – Fourier analysis of Franhaufer diffraction - Zone plate – Applications of the Fourier transform to diffraction – Apodization and spatial filtering - Holography - Recording and reconstruction of wave fronts.

Module IV

Nonlinear Optics - Polarization response of materials to light – Nonlinear Wave equation – Optical rectification – second Harmonic Generation – Phase matching – Sum and difference Frequency generation – Third harmonic generation – Intensity dependent refractive index - self focusing - B integral – Optical Parametric oscillator –Two photon absorption.

Text Books:

1. G. R. Fowles, Introduction to modern optics 2nd Ed., Dover Publications (1975).
2. E Hecht and A R Ganesan, Optics 4th Ed., Pearson (2008).
3. Fibre optics and Optoelectronics, R.P. Khare, Oxford University Press, (2004).
4. W T Silfvast, Laser Fundamentals 2nd Ed., Cambridge University Press
5. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press, 2003.

Reference Books:

1. M. Born and E. Wolf, Principles of Optics 7 th Edition, Cambridge University Physics (2013).
2. Bahaa E . A. Saleh and Malvin Carl Teich , Fundamentals of Photonics 2 nd Ed., Wiley.
3. Optoelectronics: An Introduction, J. Wilson and J.F.B. Hawkes, PHI, (2000).

48: Non-linear Optics

Course Code: 48
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

Aquire the modern ideas on Non-linear optics.

Course Outcomes

CO	CO Statement	CL
CO1	Get a thorough knowledge of polarizability and wave propagation in dielectric material.	Understand
CO2	Get a clear knowledge of second harmonic generation, four wave mixing, phase-conjugation, etc.	Understand
CO3	Get good hand on the ideas of resonating oscillators.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	0	1	1
CO2	2	1	0	0	1
CO3	2	1	0	0	1

Module I

Review of the concepts of polarizability and dielectric tensor of a medium. Frequency dependence of the dielectric tensor – wave vector dependence of the dielectric tensor – electromagnetic waves in an isotropic dielectrics.
Nonlinear dielectric response of matter – frequency variation of the nonlinear susceptibilities – wave vector dependence of the nonlinear susceptibilities.

Module II

Second harmonic generation – perturbation theory – phase matching evolution of SHW under phase matching conditions.
Four wave mixing spectroscopy – optical phase conjugation – nonlinear materials.

Module III

Scattering of light – Raman scattering – Quantum theory of Raman scattering – Brillouin scattering. Interaction of atoms with nearly resonant fields – wave function under near resonant conditions. Bloch equations – self induced transparency.

Module IV

Fibre optics – normal modes of optical fibres – nonlinear Schrödinger equations – linear theory.
Basic concepts of solitons and non-linear periodic structures. Effect of fibre loss – effect of wave guide property of a fibre – conditions of generation of a solitons in optical fibres.

Text Books:

1. D.L. Mills, Nonlinear Optics, Springer, 2nd,ed. (1998)

Reference Books:

1. F.Zernike and J.E. Midwinter, Applied Nonlinear Optics
2. G.C. Badwin, Nonlinear Optics
3. A. Hasegawa, Optical Solitons in Fibres

49: Solar Photovoltaic Technology

Course Code: 49
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of the course is to develop a general understanding of the need for clean energy sources and the potential and application of photovoltaic (PV) technology to generate power. The course will give an insight into the fabrication of solar cells in the laboratory and industrial scale, module fabrication and power generation using PV in off-grid and grid-connected systems.

Course Outcomes

CO	CO Statement	CL
CO1	Explain the working principle of solar cells.	Understand
CO2	Differentiate the fabrication and performance differences between different c-Si wafer technologies and between c-Si and thin film PV technologies.	Understand, Analyse
CO3	Illustrate cells and their interconnection.	Understand
CO4	Calculate the power and energy produced by a solar module.	Apply
CO5	Explain the differences and design aspects of off-grid and on-grid PV systems and futuristic applications of solar energy.	Analyse
CO5	Simulate Si solar cell performance and solar power generation at a place.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1
CO4	3	1	3	3	1
CO5	3	1	3	3	1

Module I

Introduction: Energy scenario - Fossil fuel and Climate change - Renewable Energy sources - Integrating Renewable Energy - Renewable energy scenarios - Economic Analysis of Renewable Energy System - Photovoltaics - history of photovoltaics - status of Photovoltaics - Grid Parity - Challenges - trends in photovoltaic technology - Policy Impacts - PV market growth scenarios - Solar radiation: Solar constant - Solar Spectra - Air Mass - Global radiation - Position of the Sun - Solar Insolation.
Physics of Solar cells: Fundamental Properties of Semiconductors - Band model - Doping - Semiconductor types - absorption of light - recombination - p-n junction - Solar cells - Solar cell parameters - Spectral response - Upper limits of cell parameters - Thermodynamic limit - the Schokley-Quiesser limit - effect of temperature - effect of parasitic resistances.

Module II

Solar PV technologies (qualitative)

First generation: Silicon wafer based technology: Design of c-Si solar cell - loss mechanism - high-efficiency approaches - PERL and PERC cells - Interdigitated back contacts - TOPCon - heterojunction solar cells - lab to industry requirements.
S**econd generation: Thin film technologies:** Merits and demerits of thin film technologies - Transparent conducting oxides - GaAs, amorphous-Si, CdTe and CIGS solar cells.
—bf Third generation/emerging PV technologies: Organic PV - organic-inorganic hybrid solar cells -perovskite solar cells- Quantum-dot - Hot-carrier – Up conversion and down conversion- concentrated solar cells- perovskite/Si tandem solar cells - Multijunction Solar Cells, Concentrated Solar Cells.

Module III

Solar cell to modules: Thin film solar modules by monolithic integration- silicon feedstock - production of silicon wafers - Manufacturing process of c-Si solar cells – the interconnection of cells - series and parallel connections - design and structure of PV module - production - measurement of modules - field performance- module reliability.

Module IV

PV systems: Standalone systems - grid-connected systems - hybrid systems - micro grids - smart grids - system components - system design. **Specific purpose PV application:** Agrovoltaics, Lighting, Building integrated Photovoltaics, refrigeration, telecommunications, space, fencing, water purification, navigation, solar cars, etc. **Simulations and hands-on:** introduction to PVSyst software, PC1D, AFORS-HET, Solar Module Installation, Solar Cell Characterization, field performance analysis.

Text Books:

1. S.R. Wenham, M. Green, M.E. Watt, R. Corkish, A. Sproul, Applied Photovoltaics ? 2nd Edition (2009)
2. K. Mertens, Photovoltaics: Fundamentals, Technology and Practice, John Wiley & Sons Ltd (2014)
3. Smets, K. Jager, O. Isabella, R. V. Swaaij, M. Zeman, Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems, UIT Cambridge Ltd. (2016).

Reference Books:

1. Handbook of Photovoltaic Science and Engineering - 2nd Ed. , A. Luque, S. Hegedus (editors), John Wiley & Sons Ltd (2011)
2. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and applications, 3rd Edition, PHI Learning Pvt. Ltd. (2019).
3. Jenny Nelson, The Physics of Solar Cells, Imperial College Press (2003).
4. Godrfrey Boyle (Eds), Renewable Energy: Power for a sustainable future, Oxford University Pres (2012).
5. S.P. Sukhatme, J.K. Nayak, Solar Energy 4th Edn, McGraw-Hill Education (2017)

6. SM Sze and Kwok K Ng, Physics of semiconductor devices, third edition ,John Wiley & Sons (2007)
7. R.F. Pierret, Semiconductor Device Fundamentals
8. D. A. Neamen and D. Biswas ,Semiconductor Physics and Devices

50: Sophisticated Material Characterization Techniques

Course Code: 50
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To train the students on the fundamentals of structural characterization of materials and to understand the usefulness of different characterization techniques.

Course Outcomes

CO	CO Statement	CL
CO1	Get good fundamental understanding, on different types of sophisticated material characterisation techniques.	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1

Module I

X-ray diffraction - X-ray methods - Production of X-rays and X-ray Spectroscopy - Instrumental units - Detectors for the measurements of radiation - Semiconductor detectors - Direct X-ray methods - Powder method - rotating crystal method - specimen preparation - -Single crystal diffractometer – Electron diffraction-Neutron diffraction- Reflection high energy electron diffraction (RHEED), XPS-principle-Instrumentation and applications-X-ray topography(XRT)- Rutherford Back Scattering analysis(RBS)- XRF (X-ray fluorescence)- Synchrotron radiation- Applications (Qualitative) – XANES-XAFS.

Module II

Morphological studies Optical microscope, Electron matter interaction- Fundamental principle and instrumentation and applications of Scanning Electron Microscope (SEM)- Transmission Electron Microscope (TEM) - Scanning transmission electron microscopy (STEM)- Atomic Force Microscope- Elemental composition analysis-EDX-EELS- Auger electron spectroscopy (AES)- Optical measurements-UV-visible spectroscopy- Determination of band gap of semiconductors- Atomic emission spectrometry.

Module III

Absorption and Emission spectroscopy - Nature of electromagnetic radiation - Atomic energy level-Raman effect - Raman Spectroscopy- Instrumentation -Infrared spectroscopy - Near IR - Mid IR - Far IR Region - Correlation of infrared spectra with molecular structure - structural Analysis - Radiation sources - Detectors - Thermal Detectors -Spectrophotometers - Fourier Transform Interferometer Quantitative analysis- Sample handling. - Luminescence –Photoluminescence(PL) spectroscopy–Nuclear magnetic Resonance Spectroscopy - Basic principles - Quantitative analysis-Dyanamic Light scattering- Secondary ion mass spectroscopy (SIMS).

Module IV

Thermal analysis - Differential Thermal Analysis - Instrumentation – Differential Scanning calorimetry - Thermogravimetry - Instrumentation - Methodology of Differential Scanning Calorimetry and Thermo Gravimetric Analysis - Conductance method – Electrical conductivity- Measurement of electrical conductance - Measurement of dielectric constant- Hall Mobility – Magnetic measurements-SQUID magnetometer- Fundamentals of cyclic voltammetry CV measurements.

Text Books:

1. B.D. Cullity, Element of X-ray Diffraction, Addison Wesley Publication, 1978.
2. X.F. Zong, Y.Y.Wang, J. Chen, Material and Process characterization for VLSI, World Scientific, New Jersey, 1988.
3. H.H.Willard, D.L.Merrti, Dean and Settle, Instrumental methods of analysis, CBS publishers.1992.
4. Yang Leng, Materials Characterization Introduction to Microscopic and Spectroscopic Methods; Wiley-VCH-Second Edition.
5. P.E. J. Flewitt and R K Wild Physical methods for Materials Characterization, IOP Publishing (2003).
6. P.Duke ; Synchratron radiation, Oxford university press 2000.
7. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
8. Zoski, C. G., Ed. Handbook of Electrochemistry; Elsevier: Amsterdam, The Netherlands, 2006.
9. John Clarke , Alex I. Braginski; The SQUID Handbook: Fundamentals and Technology of SQUIDs and SQUID Systems- Wiley-VCH.
10. Banwell and E M McCash, Fundamentals of Molecular Spectroscopy; McGraw-Hill Education (India) Pvt Limited, 2001.

51: Ultrashort Pulse Lasers and Applications

Course Code: 51
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course is on intense femto-second lasers and applications with emphasis on the current trends on the subject. Learning will be through lectures, books, journal articles and recent reviews on the subject.

Course Outcomes

CO	CO Statement	CL
CO1	Illustrate process of generation, amplification, and measurement of ultrashort lasers	Understand
CO2	Analyse high power relativistic and non-relativistic laser interaction with gaseous and condensed media.	Apply, Analyse
CO3	Evaluate Research Opportunities and technology of intense field interaction physics.	Analyse
CO4	Develop lifelong learning skills through research	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	1	1
CO2	2	1	3	1	1
CO3	2	1	3	1	1
CO4	2	0	3	0	2

Module I: Femtosecond Lasers

Femtosecond laser oscillators - Mode locking - Kerr lens mode locking - Group velocity dispersion–Chirped Mirrors - Time bandwidth product - bandwidth limited pulses - Ti: Sapphire laser - chirped pulse amplification - regenerative amplifiers - multipass amplifiers –Ultrafast pulse measurements - intensity autocorrelation - cross correlation - FROG and SPIDER.

Module II: Laser Interaction with gas phase

Laser interaction with low density Gas - Ionization-Multiphoton ionization - Tunnel ionization - Keldysh Approximation - Over the barrier ionization - Laser interaction with Clusters - Generation of rare gas clusters - cluster diagnostics through Rayleigh scattering – Properties of clusters – cluster ionization – Nano plasma model – Expansion of clusters – Coulomb explosion – Hydrodynamic expansion.

Module III: Interaction with condensed media

Basics of a plasma – Plasma density, plasma temperature, Debye length plasma frequency, critical density - Laser interaction with solids above damage threshold - Inverse bremsstrahlung absorption – collisional absorption – resonance absorption (Brunel heating) – vacuum heating - Laser produced plasma – Free-free, free-bound and line radiations in a plasma.

Module IV: Applications of Intense Lasers

Transient absorption spectroscopy - THz radiation - Two photon polymerization and direct laser 3D printing - High harmonic generation (re-collision picture) – Attosecond pulses - X-ray sources from laser-solid and laser-cluster interactions – Water window radiation – Laser Wakefield acceleration (LWFA) of electrons – Inertial Confinement Fusion.

Text Books: Units I & II

1. Claude Rulliere, Femtosecond Laser Pulses – Principles & Experiments 2 nd Ed., Springer (2005).
2. Jean-Claude Diels and Wolfgang Rudolph Ultrashort Laser Pulse Phenomena, Elsevier (2006)

Unit III

1. W L Kruer, The Physics of Laser-plasma Interactions, Addison-Wesley (1988).
2. F F Chen Plasma Physics and Controlled Fusion, 2 nd Ed., Plenum Press (1984)

Unit IV

1. Jean-Claude Diels and Wolfgang Rudolph Ultrashort Laser Pulse Phenomena, Elsevier (2006).
2. Soft x-rays and Extreme Ultraviolet Radiation: Principles and Applications, David Atwood, Cambridge University Press, 1999.

Level 500 Electives

70: 2D Materials

Course Code: 70
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To introduce the field of 2D materials, different classes and their properties.

Course Outcomes

CO	CO Statement	CL
CO1	To familiarise with low dimensional structures and their properties.	Understand
CO2	To learn about 2D material families (Graphene, 2D transition metal chalcogenides/carbides)	Understand
CO3	To familiarise with properties and applications of 2D materials	Understand
CO4	To introduce 2D topological materials	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	1	2	0
CO2	1	0	1	2	0
CO3	1	0	1	2	0
CO4	1	0	1	2	0

Module I

Schrodinger equation for an electron in a crystal- Concept of quasiparticles: electron, hole and exciton, Low dimensional structures: quantum wells, quantum wires and quantum dots. Graphene-Carbon and its allotropes-Dispersion Relation of Graphene - Dirac Points and Dirac Cones - Opening Gaps in Graphene - Electronic Properties of Graphene. Relationship between Dispersions of the 1-D and 2-D Systems, Metal contacts to graphene- Chemical bonding of metal with graphene-electrochemical equalization- orbital hybridization-characteristics of metal contact to graphene- applications of Graphene.

Module II

Introduction to 2D transition metal dichalcogenides (TMDC). Atomic and electronics Structure: Structure of individual triple layers – Bulk structure of polymorphs–Van der Waals Interlayers bonding-Electronic Structures. Raman and electronic spectra of TMDCs. Synthesis of Transition Metal Dichalcogenides – Top down Method:- Mechanical Exfoliation –Liquid Exfoliation-Electrochemical Exfoliation – Bottom up Method:-Chemical Vapour (CVD) – Pulsed Laser Deposition (PLD). Properties: Mechanical Properties-Thermal conductivity –Thermoelectric properties- optical properties-applications of TMDC.

Module III

Introduction to 2D transition metal carbides and nitrides, The M n+1 AX n phases- precursors for MXenes, Top down MXene synthesis (selective etching), Bottom up synthesis of 2D transition metal carbides and nitrides, Effect of synthesis methods on the structure and defects of two dimensional MXenes, MXene surface chemistry, Techniques of MXene delamination into single flakes, MXene films, coatings and bulk processing, Predicted electronic, magnetic, mechanical and optical properties of MXenes- applications of MXenes.

Module IV Two dimensional topological materials, Dirac/Weyl equation, topological insulators, Weyl semimetals, topological superconductors, electron transport in two dimensional topological materials, Weyl fermions in condensed matter systems, Fermi arcs, intrinsic anomalous Hall effect, magnetic breakdown and Klein tunnelling effect, Landau level collapse effect - applications of 2D topological materials.

Text Books :

1. Munarriz Arrieta, Modelling of Plasmonic and Graphene Nanodevices, Springer 2014.
2. S.V. Gaponenko, Optical properties of Semiconductor Nano crystals, Cambridge university press 1998.
3. Vasilios Georgakilas, Functinalization of Graphene, Wiley - VCH Verlag GmbH & Co. KGaA, 2014.
4. Two-DimensionalTransition-Metal Dichalcogenides, Alxander V Kolobov, Junji Tomenaga , https://www.springer.com/series/856.
5. Y. P. Venkata Subbaiah, K. J. Saji, and A. Tiwari, 'Atomically Thin MOS2: A Versatile Non-graphene 2D Material ,' Adv. Funct. Mater., vol. 26, no. 13, pp. 2046–2069, 2016, doi: 10.1002/adfm.201504202.
6. Advanced 2D materials , Editors : Ashutosh Tiwari,Mikeal Syvajarvi DOI:10.1002/9781119242635.
7. 2D Metal Carbides and Nitrides (MXenes), Structure, Properties and Applications, Editors: Anasori, Babak, Gogotsi, Yury (Eds.)
8. Transport in two-dimensional topological materials: recent developments in experiment and theory (Dimitrie Culcer et al 2020 2D Mater. 7 022007).
9. Weyl semi-metals : a short review Sumathi Rao Harish-Chandra Research Institute, Chhatnag Road, Jhusi, Allahabad 211 019, India.
10. Quasiparticle interference on type-I and type-II Weyl semimetal surfaces: a review Hao Zheng & M. Zahid Hasan.

71: Advanced Magnetism and Magnetic Materials

Course Code: 71
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

1. A postgraduate level course in Advanced Magnetism and Magnetic Materials will help in student having a thorough understanding of magnetism in condensed matter.
2. This course will equip the student with required prerequisites to proceed with a Ph.D. program in condensed matter physics or with a scientific position in magnetic materials industry.

Course Outcomes

This course is a postgraduate level course in magnetic materials. The level of treatment presumes familiarity with differential calculus as well as introductory atomic physics, statistical mechanics, and quantum mechanics of solids.

CO	CO Statement	CL
CO1	Articulate knowledge of ferromagnetism, ferrimagnetism and antiferromagnetism in materials.	Understand
CO2	Demonstrate a working understanding of permanent magnets, magnetic data storage, and magnetic refrigeration	Understand
CO3	Explain different types of interactions in a magnetic solid and ordered magnetic structures	Understand
CO4	Understand the origins of magnetic anisotropy and correlate the technical magnetic properties with the underlying microstructure of the material	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	0	1
CO2	3	1	2	0	1
CO3	3	1	2	0	1
CO4	3	1	2	0	1

Module I

Interactions in ferromagnetic materials: Weiss molecular field theory - Origin of the Weiss molecular field - Collective-electron theory of ferromagnetism – spontaneously split bands-Ferromagnetic domains - Observing domains - The formation of domains – Domain walls – width of domain walls- Magnetization and hysteresis of multidomain ferromagnets and single domain ferromagnets-The Stoner-Wohlfarth Model-Magnetic nanoparticles and superparamagnetism-Field cooled (FC) and zero field cooled (ZFC) magnetisation measurements in superparamagnetic systems.

Module II

Antiferromagnetism: Neutron diffraction - Weiss theory of antiferromagnetism - Cause of negative molecular field – Indirect exchange in ionic solids: superexchange interactions, Indirect exchange in metals-The RKKY interaction- The effect of a strong magnetic field-spin-flip and spin-flop process-Applications-Exchange bias effects in ferromagnet/antiferromagnet bilayer systems. Ferrimagnetism: Weiss theory of ferrimagnetism – compensation temperature-Ferrites-cubic ferrites-Normal and inverse spinel-examples.

Module III

Magnetic anisotropies-Magnetocrystalline anisotropy-Origin of magnetocrystalline anisotropy- symmetry of magnetocrystalline anisotropy-shape anisotropy-demagnetising fields-Induced magnetic anisotropy-magnetic annealing-Roll anisotropy-Magnetostriction-effect of magnetostriction on anisotropy.

Module IV

Industrial applications of magnetic materials-Soft magnetic materials-amorphous and nanocrystalline soft magnets-permanent magnets-Rare-earth-transition metal alloy based permanent magnets- Alternatives for rare earth permanent magnets-coercivity mechanism in permanent magnets-Magneto caloric effect and magneto caloric materials-Magnetic multilayers-Magneto resistance-giant magneto resistance-spin valves-High density magnetic data storage

Text Books:

1. Magnetic Materials Fundamentals and Applications - Nicola A. Spaldin, Cambridge University Press, 2003 [Module 1,2 and 3].
2. Magnetism in Condensed Matter-Stephan Blundell-Oxford University Press, 2001 [Module 1,2, and 3].
3. Physics of Magnetism and Magnetic Materials - K.H.J Buschow and F.R De Boer, Kluver Academic Publishers, London, 2003 [Module 4]
4. Nanoscale Magnetic Materials and Applications - Editors: J.Ping Lu, Eric Fullerton, Oliver Gutfleish, David J. Sellmyer, Springer, 2009 [Module 4]

Reference Books:

1. Introduction to Magnetic Materials - B.D. Cullity and C.D. Graham. Addison-Wesley, 1972.
2. Introduction to Magnetism and Magnetic Materials - D. Jiles. Chapman & Hall, 1996.

72: Advanced Mathematical Physics

Course Code: 72
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To equip the students to use some of the advance topics of mathematical physics.

Course Outcome

CO	CO Statement	CL
CO1	Acquire an in-depth knowledge about ordinary and partial differential equations and various methods of finding their solutions	Understand, Apply, Analyse
CO2	Understand the concepts, terminology and principles of analysing groups	Understand, Apply, Analyse
CO3	Learn the terminology, concepts and principles of analysing tensors. Learn tensor algebra	Understand, Apply, Analyse
CO4	Learn Christoffel symbols and Reimann curvature tensor which are crucial to understand general relativity	Understand, Apply
CO5	Understand basics of stochastic differential equations	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	1	1	0
CO2	2	2	1	1	0
CO3	2	2	1	1	0
CO4	2	2	1	1	0

Module I

Review of solving first and second order ordinary differential equations. Review of solving first order partial differential equations. Sturm - Liouville theory: eigenvector expansions; Hilbert spaces; self-adjoint operators; eigenfunction expansions; existence of eigenvalues and completeness of eigenfunctions; spectral theory. Classification of second order PDE s hyperbolic, parabolic and elliptic equations. Green function methods for PDEs, Laplace transform and Fourier transform solutions.

Module II

Contravariant and covariant tensors - transformation rules - direct product, con-traction, quotient rule. Metric tensor - lowering and raising of indices - covariant derivatives -Christoffel symbols. Riemann curvature tensor.

Module III

Weiner process and white noise, Stochastic integrals, Ito calculus, stochastic differential equations, The Fokker-Plank equation, Brownian motion, numerical simulations.

Module IV

Definition of a group- Cyclic groups -Group multiplication table - Isomorphic groups - Group of permutations and Cayley's theorem - Subgroups and cosets - Conjugate classes and invariant subgroups - Group representations - symmetry group D2 and D3 - One-dimensional unitary group U(1) Orthogonal groups SO(2) and SO(3) - SU(n) groups.

Text Books :

1. Mathematical Methods for Physicists Paperback (7th Edition), Arfken, Elsevier (2012).
2. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).
3. Jon Mathews and Robert Walker,Mathematical Methods of Physics, Benjamin/Cummings Publishing Co. ISBN 0805370021.

Reference Books :

1. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2001).

73: Advanced Solid State Physics

Course Code: 73
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To make the students learn modern developments in the field of condensed matter physics particularly to those who wish to do research in this area.

Course Outcomes

CO	CO Statement	CL
CO1	To understand the different perspectives of the carrier absorption and its transport properties	Understand
CO2	To familiarize with the theoretical tools like density of states etc	Understand
CO3	To familiarize with the modern ideas like, quantum well and the associated properties	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	1	2	0
CO2	1	0	1	2	0
CO3	1	0	1	2	0

Module I

Optical absorption: Free carrier absorption - optical transition between bands - direct and indirect - excitons - photoconductivity - general concepts - model of an ideal photoconductor - traps - space charge effects - crystal counters - experimental techniques - Transit time. Luminescence in crystal - excitation and emission - decay mechanism - Thallium activated alkali halides - model of luminescence in sulphide phosphors - electroluminescence.

Module II

Density of states - classification of solid into metals, semimetals, semiconductors and insulators - Calculation of number of carries in intrinsic semiconductor - Fermi level - carrier concentration in impurity semiconductors -electronic degeneracy in semiconductors. Equation of motion of electrons in a band - Effective mass and concept of holes - Boltzmann Transport equation. contact potential - metal-semiconductor contact - Schottky boundary layer - injecting contacts - surface states.

Module III

Quantum wells and low dimensional systems: Electron confinement in -infinitely deep square well and square well of finite depth - confinement in two and one dimensional well - ideas of quantum well structures, quantum dots and quantum wires - methods of preparation of nanomaterials: top down and bottom up approaches: wet chemical, self assembled vapour, phase condensation.

Module IV

Growth of single crystals - general ideas. Thin film preparation techniques - thermal and electron gun evaporation - dc and rf sputtering - amorphous solids : preparation techniques - applications. Classification of liquid crystals - applications of liquid crystals - ceramic processing techniques - electrical and mechanical properties - composite materials.

Text Books:

1. Introduction to Solid State Physics, 8th Ed., C. Kittel, Wiley, (2005)
2. Solid State Physics, A. J. Dekker, Macmillan (2000)
3. Electronic Properties of Crystalline Solids, R. H. Bube, Academic Press Inc (1974)

Reference Books:

1. Lectures on Solid State Physics, G. Busch and H. Schade, Pergamon Press (1976)
2. Theoretical Solid State Physics, A. Haug, Pergamon Press (1972)
3. Solid State Physics, N. W. Ashcroft, N. D. Mermin Holt, Rinehart and Winston, New York, 1976

74: Computational Physics

Course Code: 74
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To introduce students to numerical methods and computational techniques for solving problems in various areas of Physics and Mathematics using Computers. This will prepare them for PhD level research or a career in the Industry, where scientific computing is widely used.

Main Prerequisite

Bachelor level understanding of Physics and Mathematics.

Course Outcome

CO	CO Statement	CL
CO1	Develop skills in solving problems in various areas of Physics using appropriate numerical methods and simulation techniques, on a Computer	Understan, Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	1	2	0

Module I

Introduction and Objectives of Computational Physics, Basic Programming techniques and data visualization. Machine representation, Numerical precision and stability, Errors. Review of Numerical Methods: Root finding, Numerical Differentiation, Numerical Integration, Interpolation Methods, Matrices and Linear Algebraic Equations, Ordinary Differential Equations. Data Fitting, Fourier Transforms, Optimization methods.

Module II

Simple harmonic motion, damped and driven oscillator. Nonlinear Dynamics and Chaos: Nonlinear oscillations, Phase Diagrams for Nonlinear systems. Chaos: Discrete and Continuous systems. Few-Body Problems.

Module III

Motion of classical electrons in crossed electric and magnetic fields. Partial differential equations: Laplace's equation, Poisson's equation, diffusion equation. Numerical solution of Schroedinger equation.

Module IV

Molecular dynamics: Theory, Integration methods, Measurement of static and dynamic properties. Langevin dynamics simulations for Brownian motion. The Monte Carlo method: Probability distribution functions, random number generation, Monte Carlo integration, importance sampling, Random walks and the Metropolis Algorithm, Application to model systems.

Text Books :

1. An Introduction to Computer Simulation Methods: Applications to Physical Systems - Gould, Tobochnik & Christian, 3rd Edition, Addison Wesley (2006).

2. Basic Concepts in Computational Physics - Stickler and Schachinger, Springer (2013).

3. Computational Physics: Problem Solving with Computers - Landau and Paez, 2nd Edition, John Wiley & Sons (2007).

4. Computational Physics - Nicholas J Giordano and Hisao Nakanishi, 2nd Edition, Pearson-Prentice Hall (2006).

5. Computational Physics - P. Scherer, Springer (2010).

Reference Books :

1. An Introduction to Numerical Analysis - K.E. Atkinson, 2nd Edition, John Wiley & Sons (1989).

2. An Introduction to Computational Physics - Tao Pang, 2nd Edition, Cambridge University Press (2006).

75: Gravitation and Cosmology

Course Code: 75
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

Provide a basic introduction to the general theory of relativity and its applications in astrophysics. Specific objectives are as follows.

- Introduce tensor algebra and Einstein's general theory of relativity.
- Apply the general theory of relativity to various astrophysical systems.
- Introduce the modern theory of cosmology as an application of general theory of relativity.

Course Outcomes

CO	CO Statement	CL
CO1	Learn tensor algebra and using it they will understand the general theory of relativity.	Understand
CO2	Apply general theory of relativity to various astrophysical systems like planetary motion, black holes and gravitational waves	Understand
CO3	Understand models of expanding Universe in connection with the general theory of relativity	Understand
CO4	Familiarize with concepts of exotic components of matter in the Universe like dark matter and dark energy	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	1	2	0
CO2	1	2	1	2	0
CO3	1	2	1	2	0
CO4	1	1	1	2	0

Module I

Tensor Analysis: Tensors ; Contravariant and covariant tensors; direct product; contraction; inner product; quotient rule; tensor densities, dual tensors. Metric tensor, Parallel transport; Christoffel symbol; Covariant derivative; Riemannian geometry, Riemann curvature tensor; Ricci tensor; Equation of geodesics.

Module II GTR: Drawback's of Newtonian theory of gravity, Mach's principle, Principle of equivalence; consequences of principle of equivalence (bending of light, redshift, time dilation); Gravity as curvature of space-time; Einstein equation; reduction to Newtonian form.

Module III

Astrophysical Applications of Einstein's equation: Schwarzschild solution: derivation, Schwarzschild singularity, gravitational redshift, particle orbits - precession of the perihelion of planet Mercury, light ray orbits - the deflection and time delay of light. Linearized gravitational waves.

Module IV

Cosmology: Cosmological Principle, Hubble's law, FRW model of the universe:- FRW metric, cosmological redshift, open, closed and flat universes, matter dominated and radiation dominated universes, Particle horizon and event horizon, primordial nucleosynthesis, CMBR, Flaws of the FRW model. Jean's mass in the expanding universe, evolution of the Jean's mass. Dark matter, recent acceleration of the universe, Dark energy. (only introductory ideas.)

Text Books:

1. Gravitaion and Cosmology, S. Weinberg, ,John Wiley & Sons (1972)
2. A First Course in General Relativity, Schutz, Bernard. New York, NY: Cambridge University Press, 1985. ISBN: 9780521277037.
3. Introduction to cosmology, J. V. Narlikar, Cambridge University Press, 3rd edition (2002)

Reference Books:

1. Gravity, J. B. Hartle, Pearson Education.(2003).
2. Gravitation, Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler,(1973).
3. Gravitation - Foundations and Frontiers , T. Padmnabhan, cambridge University Press, New York (2010)

76: Molecular Physics and Laser Spectroscopy

Course Code: 76
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To impart the modern ideas and applications of Molecular Physics and spectroscopy.

Course Outcome

CO	CO Statement	CL
CO1	Have basic knowledge of the chemical bonding in molecules and also adequate knowledge in Valence theory	Understand
CO2	Posses the knowledge about the structure properties of polytropic molecules including water molecule.	Understand
CO3	Know the spectra of different molecules, which will enable to identify the molecule through a spectroscopic study	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Theory of chemical bonding in diatomic molecules Born-Oppenhemier approximation – Molecular orbital theory LCAO approximation. – H_2 molecule – Valence-Bond theory – H_2 molecule – Heitler and London treatment of H_2 molecule.
LCAO-MO treatment of general diatomic molecule – Valence-Bond treatment of diatomic molecules – Electronic states and Term symbols – Hund's coupling cases.

Module II

M.O. theory of simple polyatomics and application to water molecule, Huckel M.O. theory and its application to ethylene, allyl and butadiene systems.
Microwave spectroscopy – Rotational spectrum of non-rigid diatomic molecules – Stark effect in rotational spectra. Nuclear Quadrupole hyperfine interaction due to single nuclear spin. Zeeman effect in rotational spectra. Description of microwave spectrometer.

Module III

Electronic spectra of diatomic molecules – Rotational Structure of electronic bands – PQR branches – Bandhead formation and shading – Combination relations for evaluation of rotational constants.
Laser systems – three and four level schemes – solution of rate equations for three level systems – System description of semiconductor diode lasers – Ti-saphire lasers and Tunable Dye Lasers.

Module IV

Description of diode laser spectrometer – examples of diode laser spectra of diatomic molecules. Dunham representation of re-vibrational transitions. (basic ideas only)
CW dye laser spectrometers - basic ideas of intermodulated fluorescence spectroscopy – Microwave frequency - optical double resonance spectroscopy and infrared optical double resonance spectroscopy

Text Books:

1. R.K. Prasad, Quantum Chemistry, NEW AGE; Fourth edition (2010)
2. W. Gordy and E.L. Cook, Microwave Spectroscopy, John Wiley & Sons (1984)
3. G. Herzbera, Spectra of Diatomic Molecules, Van Nostrand Reinhold Company (1979)

Reference Books:

1. Qrazio Svelto, Principles of Lasers
2. Eizi Hirota, High Resolution Spectroscopy of Transient Molecules
3. A. Mooradian.T., Jaeger and P. Stockseth, Tunable Lasers and Applications
4. A.B. Budgor, L. Esterowitz and L.G. Deshazer, Tunable Solid State Lasers-II

77: Non-equilibrium Statistical Physics

Course Code: 77
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

1. To introduce the important concepts in non-equilibrium physics.

2. To learn about natural systems and exact models that exhibit such processes.

Course Outcome

CO	CO Statement	CL
CO1	Get a grasp on various theoretical methods useful in understanding non-equilibrium phenomena	Understand
CO2	Solve problems in stochastic processes and to predict the distributions of random variables.	Apply
CO3	Differentiate non-equilibrium systems from equilibrium systems wherever applicable.	Analyse
CO4	Apply large deviation theory in physical systems.	Apply
CO5	Understand the technical terminology, and to follow the scientific literature of past and recent advances in the field.	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	2	2	1
CO2	3	2	3	3	1
CO3	3	2	3	3	1
CO4	3	1	3	3	1
CO5	3	1	3	3	1

Module I

Introduction to stochastic processes: basics of probability theory, Random numbers, Probability distributions, Moments, cumulants, generating functions Central limit theorem, Levy stable distributions.

Module II

Brownian motion, first passage properties, Markov processes, Master equation, Detailed balance condition, Langevin equations and Fokker-plank equation, Solutions to the Fokker plank equation for simple systems

Module III

Correlations, response, Fluctuation dissipation theorem, Linear response theory, Large deviation theory, Fluctuation relations.

Module IV

Non-equilibrium phenomena, Nucleation, Spinodal decomposition, Active and driven systems, Glassy systems, granular matter Exactly solvable systems

Text Books :

1. N G Van Kampen, Stochastic Processes in Physics and Chemistry (North-Holland Personal Library) North Holland; 3rd edition.
2. V Balakrishnan, Elements of Nonequilibrium statistical mechanics, Ane books, Delhi & CRC Press (2008)
3. R. Kubo, M Toda, N. Hashitsume, Statistical Physics II:Non-equilibrium statistical Mechanics, Springer-verlag, Berlin (1985)
4. A Kinetic view of statistical physics: Pavel L. Krapivsky, Sydney Redner, Eli Ben-Naim Cambridge University Press, (2013)

Reference Books :

1. Non-equilibrium Statistical Mechanics, Robert Zwanzig, OUP USA (2001)
2. Non-equilibrium Statistical Physics: Linear Irreversible Processes, Noelle Pottier OUP (Oxford Graduate Texts)
3. The mechanics and statistics of Active matter, Sriram Ramaswamy, Annual Review of Condensed Matter Physics 323-345 (2010).

78: Phase Transition and Critical Phenomena

Course Code: 78
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To understand how to develop the physics of a system with many interacting components in equilibrium.
Understand the physics of phase transitions and related critical phenomena.

Course Outcomes

CO	CO Statement	CL
CO1	Get an in-depth understanding of equilibrium statistical mechanics.	Understand, Apply, Analyse
CO2	Acquire the ability to develop a quantitative theory of a system with many interacting degrees of freedom using exact and approximate methods	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1

Module I

Review of equilibrium statistical physics, statistical physics of interacting systems: Cluster expansion for a classical gas. Virial expansion of the equation of state. Evaluation of the Virial coefficients. Van-Der-Walls equation of state and the liquid-vapor phase transition.

Module II

Ising models on lattices. Exact solution in $1D$ using transfer matrix, High and low temperature behavior of $2D$ model. Concepts related to phase transitions: Critical behavior, Order parameter, Peierls-Griffiths argument, Critical exponents.

Module III

Computer simulation methods, Metropolis algorithm. Mean field approach. Solution of d-dimensional Ising model. Evaluation of mean-field exponents. Landau theory of phase transition.

Module IV

Percolation phase transition. Exact solution in 1D and Bethe lattice. Cluster structure. Continuum percolation. Finite size scaling and the renormalization group approach (basic ideas).

Text Books :

1. R. K. Pathria, Statistical Mechanics, 2 nd edition, Elsevier (2005).
2. Principles of equilibrium statistical mechanics, D. Chowdhury and D. Stauffer, Wiley (2000).
3. D. Stauffer and A. Aharony, Introduction to percolation theory, Taylor & Francis (2003)

Reference Books :

1. K. Huang, Statistical Mechanics, 2 nd Edition, Wiley India (2008).
2. Landau and Lifshitz, Statistical Physics, Elsevier (2005).
3. Scaling and Renormalization in Statistical Physics, John Cardy, Cambridge University Press (2002).
4. Lectures On Phase Transitions And The Renormalization Group, Nigel Goldenfeld, CRC Press (2018).

79: Quantum Computation and Information

Course Code: 79
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Prerequisites

Knowledge of basic quantum mechanics and Mathematical Physics.

Course Objectives

Course Outcomes

CO	CO Statement	CL
CO1	Get an overview of the emerging field of quantum computation and the techniques involved in that	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1

Module I

Introduction to classical computation. The Turing machine - the circuit model of computation - computational complexity (elementary ideas) - energy and information - reversible computation. Introduction to quantum mechanics - Linear vector space - Tensor products - Postulates of quantum mechanics - the EPR paradox and Bell's theorem. (relevant sections of Chapter 1 and 2 of Benenti et.al.)

Module II

The qubit - single qubit gates - controlled gates - universal quantum gates - Deutsch and Deutsch - Josza algorithms - the quantum Fourier transform - period finding and Schor's algorithm - quantum search - first experimental implementations (relevant sections of Chapter 3 of Benenti et.al.)

Module III

Classical cryptography-quantum no - cloning theorem - quantum cryptography - BB84 and E91 protocols - dense coding - quantum teleportation - experimental implementations. (relevant sections of Chapter 4 of Benenti et.al.)

Module IV

Classical information and Shannon entropy - data compression - density matrix in quantum mechanics - von Neumann etropy - quantum data compression - composite systems - Schmidt decomposition - entanglement concentration (relevant sections of Chapter 5 of Benenti et.al.)

Text Books:

1. G. Benenti, G. Casati and G. Strini, Principles of quantum computation and information (World Scientific)

Reference Books:

1. M. A. Nielson and I. L. Chuang, Quantum computation and quantum information (Cambridge University Press)

80: Quantum Field Theory

Course Code: 80
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To introduce the basic concepts and methods of classical and quantum field theory.

Course Outcomes

CO	CO Statement	CL
CO1	Understand the basics of classical field theory concepts and methods of calculation	Understand
CO2	Understand about the scalar field and Feymann propagator and it's usage	Understand
CO3	Familiarize with the idea of quantization of the filed and allied facts	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Classical field theory, Euler Lagrange equations, Hamilton formalism, conservation laws. Canonical quantization of neutral and charged scalar filed, symmetry transformations.
(Sect. 2.1-2.2, 2.4, 4.1-4.3 of Ref. 1)

Module II

Scalar fields: The invariant commutation relations, scalar Feynman propagator. Dirac fields-- canonical quantization of Dirac fields-Feynman propagator.
(Sect. 4.4-4.5, 5.1-5.4 of Ref. 1)

Module III

Canonical quantization of Maxwell's field-Maxwell's equations-Lorentz and Coulomb gauges-Lagrangian density.
Canonical quantization in Lorentz and Coulomb gauges-Coulomb interaction and transverse delta functions.
(Sect. 6.1--6.2, 7.1--7.5, 7.7 of Ref. 1)

Module IV

Interacting fields, interaction picture, time evolution operator, scattering matrix, Wick's theorem(no proof), Feynman rules(no rigorous treatment) -Moller and Compton scattering.
(Sect. 8.1-8.7 of Ref. 1)

Spontaneous symmetry breaking, scalar theory, Goldston theorem(no proof), spontaneous breaking of gauge symmetries.
(Sect. 8.1-8.3 of Ref. 2)

Text Books:

1. Field Quantization, Greiner W and Reinhardt J, Springer, (2013)
2. Quantum Field Theory, Ryder L H, Cambridge University Press; 2 edition (1996)

Reference Books:

1. Quantum Field Theory, Itzykson C and Zuber J B, Dover Publications Inc., (2006)
2. Relativistic Quantum Fields I & II, Bjorken J D and Drell S D, McGraw Hills(1965)

81: Quantum Optics

Course Code: 81
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To teach the students about the basics and sufficient advanced ideas of Quantum Optics.

Course Outcome

CO	CO Statement	CL
CO1	Acquire sufficient knowledge regarding the radiation-matter interaction	Understand
CO2	Acquire a thorough understanding of the black body radiation and laser theory	Understand
CO3	Get a clear idea about the modern concepts like, Doppler broadening, multimode field quantization, etc.	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Interaction between electromagnetic waves and matter – linear dipole oscillator method – radiative damping – coherence.
Nonlinear dipole oscillator method. Coupled mode equations cubic nonlinearity – nonlinear susceptibilities.

Module II

Atom-field interaction for two level atoms – blackbody radiation – Rabi Flopping.
Introduction to laser theory – the laser self consistency equation – steady state amplitude and frequency – stability analysis – mode pulling.

Module III

Doppler – broadened lasers – Two mode operation and the ring laser – mode locking – single mode semiconductor theory – evaluation of laser gain and index formulas – transverse vibrations and Gaussian beams.
Field quantization - single mode field quantization – multimode field quantization – single mode in thermal equilibrium. Coherent states – coherence of Quantum fields p ( ) representations.

Module IV

Interaction between atoms and quantized fields – Dressed states – Jaynes-Cummings model – collapse and revival.
Squeezed state of light – squeezing the coherent states – two side mode master equation – two mode squeezing – squeezed vacuum.

Text Books:

1. P. Meystre and M. Sargent III, Elements of Quantum Optics (2nd Ed.)

Reference Books:

1. W.H. Louisell, Quantum Statistical Properties of Radiation
2. M. Sargent III, M.O. Scully and W.E. Lamb, Laser Physics

82: Thin Film Physics

Course Code: 82
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To impart the modern ideas of thin film technologies used in various solid state physics and day today applications.

Course Outcome

CO	CO Statement	CL
CO1	Familiarise with the different thin film deposition methods.	Understand
CO2	Understand the nuclear theories of thin film formation.	Understand
CO3	Familiarise with the measurements techniques of the properties of thin films.	Understand
CO4	Get awareness and knowledge of various application of thin films in semiconductor devices and in day today life.	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1
CO4	3	1	3	3	1

Module I

Vacuum Technology: High vacuum production: Mechanical pumps – Diffusion pumps-Cryogenic pumps – Getter pumps – ion pumps- basics of ultra-high vacuum Measurement of Vacuum: McLeod gauge – Thermal conductivity gauges - Cold cathode and hot cathode ionisation gauges Designing a vacuum system- vacuum leak detection: helium leak detector, residual gas analyzer.

Module II

Thin film growth techniques: Physical Vapour Deposition: Vacuum evaporation - Evaporation theory - Rate of evaporation - Hertz-Kundsen equation - Free evaporation and effusion - Evaporation mechanisms - Directionality of evaporating molecules - vapour sources - wire and metal foils - Electron beam gun- sputtering - Glow discharge sputtering - Bias sputtering - Reactive sputtering - Magnetron sputtering - Ion beam sputtering - PLD- epitaxial films- MBE Chemical Vapour deposition: conventional CVD, Plasma enhance CVD, MOCVD, Atomic layer Deposition Film thickness measurements: Optical methods - basics of multilayer modelling- Ellipsometry -Other techniques: Electrical - Mechanical - Micro-balance - Quarts crystal monitor - X ray reflectivity.

Module III

Nucleation Theories: Condensation process - Theories of Nucleation – Capillarity theory – Atomistic theory – Comparison – stages of film growth – Incorporation of defects during growth.

Optical properties:Reflection and transmission at an interface – Reflection and transmission by a single film – Optical constants - Refractive index measurement techniques – Reflectivity variation with thickness Patterned films: lithography techniques – film etching methods.

Module IV

Electrical Properties: Electrical Properties: Sources of resistivity – sheet resistance – electron mobility- Hall Effect -TCR – Influence of thickness on resistance – Theories of size effect – Theories of conduction in discontinuous films – Electronic conduction in thin insulating films- MIS structure -Dielectric properties – D.C. conduction mechanisms – High and low field conduction – Temperature dependence – space charge limited conduction – A.C. conduction mechanisms Application of thin films: electrodes, transparent conducting oxides, thin film devices: LED, TFT, -Solar cells - optical and decorative coatings - dichroic coatings- biomedical coatings – tribological coatings.

Text Books:

1. Hand Book of Thin Film Technology, Maissel and Glang, McGraw Hill Higher Education (1970)
2. Materials science of thin films deposition and structures, Milton Ohring, Academic press, 2006.
3. Vacuum deposition of thin films, L. Holland, Chapman and Hall.
4. Glow discharge processes, B. Chapman, Wiley, New York.
5. Physics of Non-Metallic Thin Films, Dupy and Kachard, Plenum Press (1976).
6. Scientific Foundations of Vacuum Technology, S. Dushman and J.M. Lafferty, John Wiley & Sons, Inc.; 2nd Ed. (1962).
7. Thin Film Phenomena, K.L. Choppra, McGraw-Hill Inc.,US (1969).

Reference Books:

1. O. S. Heavens, Optical Properties of Thin Films, by, Dover Publications, Newyork 1991
2. Donald L. Smith 'Thin Film deposition principle and Practice's, McGraw Hill international Edition, 1995.
3. Various web resources and research papers

Five-Year Integrated M.Sc. (STATISTICS) ACADEMIC PROGRAM

Scheme of Examinations and Syllabus for
the Five-Year Integrated M.Sc. Degree
Programmes in **Statistics**

(2024 Admission Onwards)

Department Specific/Elective Core Papers for

Major, Minor and Multi-Disciplinary Courses

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Department of Statistics

Cochin University of Science and Technology

Vision

To become a global center of excellence in the conservation, creation, advancement, and dissemination of knowledge in the field of statistics and allied subjects.

Mission

- To impart quality education in statistics to achieve excellence in teaching, research and consultancy.
- To generate cutting-edge research and innovations in statistics and allied areas to enable empowerment for economic, technological and social development.
- To strengthen international collaborations to spread the wings CUSAT globally for teaching and research in statistics and allied areas.

Program Outcomes - Integrated M.Sc.

- PO1: Demonstrate a comprehensive understanding of fundamental principles and concepts in basic sciences.
- PO2: Analyze, evaluate, and synthesize complex scientific information and data using appropriate methods and techniques.
- PO3: Apply scientific reasoning and critical thinking adeptly to recognize, assess, and resolve problems encountered in various scientific contexts.
- PO4: Utilize computational power, programming languages, and modern technologies proficiently to address scientific challenges, effectively integrating technological solutions into problem-solving processes.
- PO5: Communicate scientific information effectively and demonstrate proficiency in the use of modern scientific tools and technologies for experimentation, data collection, analysis, and interpretation.
- PO6: Adhere to ethical principles and practices in the conduct of scientific research and professional activities, and work collaboratively with others.
- PO7: Engage in lifelong learning and professional development to enhance the knowledge and skills in basic sciences.

Program Specific Outcomes - Integrated M.Sc. Major in Statistics

- PSO1: Understand the role of probability and statistics in solving real life problems.
- PSO2: Apply the knowledge on modern statistical techniques relevant for today's scientific community.
- PSO3: Illustrate the need for systematic analysis of data in any scientific experiment.

- PSO4: Practise statistical knowledge for the consultancy on experimental design and field survey.
- PSO5: Develop professionally inclined statistics teachers/statistician/data scientist who have sound knowledge of the subject matter and specialized in knowledge discovery through statistical methods.
- PSO6: Apply basic theoretical and applied principles of statistics with adequate preparation to pursue a Doctoral (Ph.D.) degree or enter job force as an applied statistician.
- PSO7: Translate key statistical concepts to non-statisticians.
- PSO8: Develop proficiency in using statistical software/utility for data analysis.

Integrated M.Sc. Statistics Scheme (2024 Admissions Onwards)

Semester	Number of courses offered by the department						Total
	Major- 4 credits	Minor - 4 credits	MDC - 3 credits	AEC- 3 credits	SEC - 3 credits	VAC - 3 credits	
I	1	2	1	2^*			21
II	1	2	1	2^*			21
III	1	2	1			2^*	21
IV	4				1	1^*	22
V	5				1		23
VI	5^{**}				1		23
	Internship***						2
Total Credits /Courses	68(17); DSC 60(15); DSE 08(04)	24(6)	9(3)	12(4)	9(3)	9(3)	133
* Courses offered by the Center for Integrated Studies CUSAT ** Instead of one course with 4 credits a student may take one or two online courses to acquire 4 credits *** Not counted as a course and should be completed before the end of V^{th} semester **Exit with B.Sc. in Statistics (Total credits = 133)**							
VII	$5^{\dagger}$						22
VIII	$2^{\dagger\dagger}$ OR $4^{\dagger\dagger\dagger}$						22
† and seminar or open ended labs or online course of 2 credits †† and seminar or open ended labs or online course of 2 credits + Project with 12 credits ††† and seminar or open ended labs or online course of 2 credits + Mini Project with 4 credits							
Total Credits /Courses	Hon (Research): 112 (24+ Project (12) + Practicals (4)) Hon: 112 (26 + Mini Project (4) + Practicals (4))	24 (6)	9 (3)	12 (4)	9(3)	9 (3)	177
Exit with B.Sc.(Honours with Research) in Statistics (Total credits = 177) **Exit with B.Sc. (Honours) in Statistics (Total credits = 177)**							
IX	5 + Online (2-4 credit$^{\otimes}$)						20-24
X	$2^{\otimes\otimes}$ + Online (2-4 credit$^{\otimes}$)						20-24
Total Credits/ Courses	156 (35 + Mini project + Major project)	24(6)	9(3)	12(4)	9(3)	9(3)	221
$^{\otimes}$ Online course of 2-4 credits can be taken in IX or X Semesters, so total credit for online course is 4 $^{\otimes\otimes}$ and Major Project with 12 credits							
Exit with M. Sc. in Statistics (Total credits = 221)							

Academic pathways offered by the Department of Statistics

- **Statistics Major:**
  - 3-year UG Program: To earn a Statistics Major in a 3-year UG Program, a student must complete a minimum of 68 credits in Statistics, out of which 60 credits shall be from DSC courses and 8 credits from DSE courses.
  - 4-year UG Program (Honours): To earn a Statistics Major in a 4-year UG Program (Honours), a student must complete a minimum of 112 credits in Statistics, out of which 96 credits shall be from DSC courses and 16 credits from DSE courses.
  - 4-year UG Program (Honours with Research): To earn a Statistics Major in a 4-year UG Program (Honours with Research), a student must complete a minimum of 112 credits in Statistics, out of which 92 credits shall be from DSC courses and 8 credits from DSE courses and 12 credits from a research project.
  - 5-year PG Program: To earn a Statistics Major in a 5-year PG Program , a student must complete a minimum of 156 credits in Statistics, out of which 120 credits shall be from DSC courses and 24 credits from DSE courses and 12 credits from a research project.
- **Statistics Minor:**
  - 3-year UG Program: To earn a Minor in Statistics in a 3-year UG Program, a student must complete a minimum of 27credits in Statistics, out of which 24 credits shall be from DSC courses and 03 credits from an SEC elective.
  - 4-year UG Program: To earn a Minor in Statistics in a 4-year UG Program, a student must complete a minimum of 35 credits in Statistics, out of which 24 credits shall be from DSC courses and 3 credits from an SEC elective 8 credits from DSE courses.
- **Discipline mention in Statistics:**
  - To earn a Discipline mention in Statistics in a UG Program (3 or 4 years), a student must complete a minimum of 12 credits in Statistics from DSC courses.

Scheme

Semester I

Semester Credit: 21 (AEC: 6, Major: 4, Minor: 8, MDC: 3); Cumulative Credit: 21								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0101	Introductory Statistics	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0102	Applied Statistics	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0103	Basic Statistics	MDC	None	2-0-2	3	50	50	100

- H/W for L-T-P stands for Hours/Week for Lecture- Tutorial-Practical
- AEC – Ability Enhancement Course;
  MDC – Multidisciplinary Course;
  VAC – Value Added Course;
  SEC – Skill Enhancement Course;
  DSC - Department Specific Core:
  DSE - Department Specific Elective. Multi-Disci - Statistics Disciplinary
- Students can choose either
  - Single major path way - Statistics single Major OR
  - Major with minor pathway - Statistics Major with Mathematics/Physics/Computer Science (Artificial Intelligence) / Biological Sciences as Minor OR
  - Major with Multi disciplinary path way- Statistics Major with Mathematics and/or Physics and/or Computer Science (Artificial Intelligence) and/or Biological Sciences as Multi Disciplinary choices.

Semester II

Semester Credit: 21 (AEC: 6, Major: 4, Minor: 8, MDC: 3); Cumulative Credit: 42								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0201	Introduction to Probability Theory	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0202	Probability Distributions	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0203	Probability Theory and Random Variables	MDC	None	2-0-2	3	50	50	100

Semester III

Semester Credit: 21 (Major: 4, Minor: 8, MDC: 3, VAC: 6); Cumulative Credit: 63								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0301	Statistical Methods	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0302	Statistical Inference	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0303	An Introduction to Statistical Methods	MDC	None	2-0-2	3	50	50	100

Semester IV

Semester Credit: 22 (Major: 16, SEC: 3, VAC: 3); Cumulative Credit: 85								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0401	Discrete Distributions	STAT Major - DSC	24-810-0201	3-0-2	4	50	50	100
24-810-0402	Continuous Distributions	STAT Major - DSC	24-810-0201	3-0-2	4	50	50	100
24-810-0403	Bivariate Data Analysis	STAT Major - DSC	24-810-0101	3-0-2	4	50	50	100
24-810-0404	Sampling Theory and Methods - I	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0405	Statistical Data Analysis Using R - I	SEC	None	1-0-4	3	50	50	100

Semester V

Semester Credit: 23 (Major: 20, SEC: 3); Cumulative Credit: 108								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0501	Statistical Inference - I	STAT Major - DSC	24-810-0201/0202	3-0-2	4	50	50	100
24-810-0502	Statistical Quality Control	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0503	Operations Research - I	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0504	Time Based Data and Index Numbers	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-05xx	Elective - I	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0508	Statistical Data Analysis Using Python	SEC	None	1-0-4	3	50	50	100
Elective - I (Choose any one course)								
24-810-0505	Machine Learning	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0506	Actuarial Statistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0507	Financial Statistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100

Semester VI

Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
Semester Credit: 23 (Major: 20, SEC: 3); Cumulative Credit: 131								
						CE	ES	Total
24-810-0601	Statistical Inference - II	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0602	Design and Analysis of Experiments - I	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0603	Multivariate Methods	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0604	Survival Analysis	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-06xx	Elective - II	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0608	Statistical Data Analysis Using R - II	SEC	24-810-0508	1-0-4	3	50	50	100
Elective - II (Choose any one course)								
24-810-0605	Introduction to Data Mining	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0606	Econometrics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	0-2-0	4	50	50	100
24-810-0607	MOOC	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	0-2-0	4	-	100	100
Internship (Not counted as a course): 2 credits								

- Students can exit with B.Sc. Statistics (Total Credits=133)

Semester VII

Semester Credit: 22 (Major: 20, Seminar/Open ended labs/Online course: 2); Cumulative Credit: 155								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0701	Mathematical Methods for Statistics	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0702	Probability Theory	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0703	Family of Distributions	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0704	Sampling Theory and Methods - II	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-07xx	Elective - III	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0708	Practical-I and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
Elective - III (Choose any one course)								
24-810-0705	Categorical Data Analysis	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0707	Population Dynamics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0707	Biostatistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100

- [a] End semester evaluation based on viva voce.

Semester VIII

B.Sc (Honours) in Statistics								
Semester Credit: 22 (Major: 20; seminar/open ended labs/online course: 2); Cumulative Credit: 177								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0801	Theory of Estimation	STAT Major - DSC	24-810-0703	2-1-2	4	50	50	100
24-810-0802	Stochastic Processes	STAT Major - DSC	24-810-0702	2-1-2	4	50	50	100
24-810-0803	Advanced Techniques for Data Analysis	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0804	Mini Project	STAT Major - DSC	None	0-4-0	4	50	50[b]	100
24-810-08xx	Elective - IV	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0808	Practical-II and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
Elective - IV (Choose any one course)								
24-810-0805	Reliability Modelling and Analysis	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0806	Introduction to Information Theory	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0807	Statistical Analysis of Clinical Trials	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
Exit with B.Sc. (Honours) in Statistics (Total credits = 177)								
B.Sc (Honours with Research) in Statistics								
24-810-0801	Theory of Estimation	STAT Major - DSC	24-810-0703	2-1-2	4	50	50	100
24-810-0802	Stochastic Processes	STAT Major - DSC	24-810-0702	2-1-2	4	50	50	100
24-810-0808	Practical-II and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
24-810-0809	Project	STAT Major - DSC	None	0-12-0	12	50	50[b]	100
Exit with B.Sc. (Honours with Research) in Statistics (Total credits = 177).								

- [a] End semester evaluation based on viva voce;
- [b] End semester evaluation based on the presentation and project report.

Semester IX

Semester Credit: 22-24 (Major: 20, Online Course: 2-4); Cumulative Credit: 199-201								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0901	Testing of Hypothesis	STAT Major - DSC	24-810-0801	2-1-2	4	50	50	100
24-810-0902	Multivariate Analysis	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	24-810-0302 (To choose as DSE)	2-1-2	4	50	50	100
24-810-0903	Applied Regression Analysis	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	24-810-0302 (To choose as DSE)	2-1-2	4	50	50	100
24-810-0904	Design and Analysis of Experiments-II	STAT Major - DSC	24-810-0801	2-1-2	4	50	50	100
24-810-09xx	Elective - V	STAT Major - DSE	24-810-0503	2-1-2	4	50	50	100
24-810-0908	MOOC (2-4 credits)[c]	STAT Major - DSE	None	0-2-0	2-4	-	100	100
Elective - V (Choose any one course)								
24-810-0905	Operations Research - II	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0906	Reliability Engineering	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0907	Applications of Integral Transforms	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100

- [c] A MOOC of 2-4 credits should be opted by the student with the approval of the Department Council.

Semester X

Semester Credit: 22-24 (Major: 20, Online Course: 2-4); Cumulative Credit: 221								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-1001	Time Series Analysis	STAT Major - DSC	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1002	Project Work	STAT Major - DSC	None	0-12-0	12	50	50[b]	100
24-810-10xx	Elective - VI	STAT Major - DSE	24-810-0503	2-1-2	4	50	50	100
24-810-1007	MOOC (2-4 credits)[c]	STAT Major - DSE	None	0-2-0	2-4	-	100	100
Elective - VI (Choose any one course)								
24-810-1003	Lifetime Data Analysis	STAT Major - DSE	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1004	Spatial Statistics	STAT Major - DSE	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1005	Advanced Bayesian Computing	STAT Major - DSE	None	2-1-2	4	50	50	100
24-810-1006	Statistics for Clinical Research	STAT Major - DSE	None	2-1-2	4	50	50	100

- [b] End semester evaluation will be done based on the presentation and project report.
- [c] A MOOC of 2-4 credits should be opted by the student with the approval of the Department Council.
- Instead of taking two online courses worth 2 credits each, a student can opt for one online course worth 4 credits in the ninth semester. In such cases, the credits earned in the ninth semester will be 24, and in the tenth semester, they will be 20.
- Exit with M.Sc. in Statistics (Total credits = 221)

Semester I

Semester Credit: 21 (AEC: 6, Major: 4, Minor: 8, MDC: 3); Cumulative Credit: 21								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0101	Introductory Statistics	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0102	Applied Statistics	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0103	Basic Statistics	MDC	None	2-0-2	3	50	50	100

24-810-0101 Introductory Statistics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify different type of data and their preliminary analysis	Understand
2.	Interpret and analyse important measures of central tendency	Analyse
3.	Interpret and analyse various measures of dispersion and calculation of them	Analyse
4.	Illustrate various moments	Analyse
5.	Calculate skewness and kurtosis and their interpretations	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	3	2			3	
CO2	3	1	2				2	1
CO3	2	2		2			3	1
CO4	2	1					3	1
CO5	2	1					2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction - scope and importance of statistics; Types of data - nominal, ordinal, interval, and ratio; Graphical representation of data- bar diagram, pie diagram, histogram, frequency polygon and ogives, Box-Whisker plot, stem and leaf diagram. (10 Hours)

Module 2:

Measures of central tendency- arithmetic mean, median, mode, geometric mean, harmonic mean and weighted averages; Examples and related problems for different types of data. (14 Hours)

Module 3:

Measures of dispersion - range, quartile deviation, mean deviation and standard deviation, combined mean and standard deviation, relative measures of dispersion, coefficient of variation; Partition values- quartiles, deciles, percentiles; Examples and related problems for different types of data; Lorenz curve and Gini index. (18 Hours)

Module 4:

Raw and central moments, interrelationship among first four moments; Skewness - Pearson's, Bowley's and moment measures, kurtosis; Examples and related problems for different types of data; Practical using MS excel- introduce various charts and diagrams, calculation of measures of central tendencies, dispersion, moments and measures of skewness and kurtosis. (18 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2017). *Introductory Statistics*, 4^{th} Edition. Academic Press, India.

References:

1. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

2. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.

3. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New Delhi.

24-810-0102 Applied Statistics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Distinguish different types of data collection methods and their preliminary analysis	Understand
2.	Interpret and understand bivariate data and properties	Apply
3.	Analyse association measures for bivaraite data	Analyse
4.	Examine the relationship between two variables using the method of regression	Analyse
5.	Practice the calculation of correlation and regression methods	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2	1				2	
CO2	3	2	1				2	
CO3	3	1	2		1		3	
CO4	3	2			2		2	
CO5	2			2	2		2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Primary and secondary data, population and sample, census and survey sampling, sampling and non - sampling errors, types of sampling - simple random sampling (with and without replacement), stratified sampling, systematic sampling, cluster sampling, non-probability sampling. (10 Hours)

Module 2:

Bivariate data, scatter diagram, Pearson's correlation coefficient, properties, Spearman's rank correlation coefficient, repeated ranks, ϕ coefficient, Cramers's V, Kendall's τ - related problems. (15 Hours)

Module 3:

Principle of least squares, linear regression, regression coefficients, properties, curve fitting - for straight line, quadratic curve, exponential curves - related problems. (20 Hours)

Module 4:

Practical using MS excel- calculation of correlation coefficient for different types of data; Curve fitting of straight line, quadratic curve, exponential and power curves; Calculation of regression coefficient and regression lines, interpreting the results. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2017). *Introductory Statistics*, 4^{th} Edition. Academic Press, India.

References:

1. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

2. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.

3. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New York.

24-810-0103 Basic Statistics

Credits (H/W for L-T-P): 3 (2-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify different type of data and their preliminary analysis	Understand
2.	Interpret and analyse important measures of central tendency	Analyse
3.	Interpret and analyse various measures of dispersion and calculation of them	Analyse
4.	Illustrate various moments	Analyse
5.	Calculate skewness and kurtosis and their interpretations	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	3	2			3	
CO2	3	1	2				2	1
CO3	2	2		2			3	1
CO4	2	1					3	1
CO5	2	1					2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction - scope and importance of statistics; Types of data - nominal, ordinal, interval, and ratio; Graphical representation of data - bar diagram, pie diagram, histogram, frequency polygon and ogives. (10 Hours)

Module 2:

Averages - Arithmetic mean, median, mode, geometric mean, harmonic mean and weighted averages; Partition values; Examples and related problems for different types of data. (14 Hours)

Module 3:

Absolute measures of dispersion - range, quartile deviation, mean deviation and standard deviation, properties; Relative measures of dispersion; Examples and related problems for different types of data. (18 Hours)

Module 4:

Raw and central moments, interrelationship among first four moments, Skewness - Pearson's, Bowley's and moment measure, kurtosis; Examples and related problems for different types of data. (18 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2017). *Introductory Statistics*, 4^{th} Edition. Academic Press, India.

References:

1. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

2. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.

3. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New Delhi.

Semester II

Semester Credit: 21 (AEC: 6, Major: 4, Minor: 8, MDC: 3); Cumulative Credit: 42								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0201	Introduction to Probability Theory	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0202	Probability Distributions	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0203	Probability Theory and Random Variables	MDC	None	2-0-2	3	50	50	100

24-810-0201 Introduction to Probability Theory

Credits (H/W for L-T-P) : 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Discuss the basic principles of probability including theorems on probability and use these principles in problem solving situations	Understand
2.	Demonstrate basic probability relations including conditional probabilities and Bayes' Law	Apply
3.	Employ the definitions of univariate and bivariate random variables	Apply
4.	Calculate the density and distribution function of a random variable	Analyse
5.	Differentiate the marginal density and distribution function from the joint density function and distribution function	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2			3	3	1	
CO2	3	1		2	3	3	1	
CO3		3		1	3	3		
CO4	3	2		1	3	3		
CO5	3	2		1	3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic terminologies - introduction, random experiments, sample space, events and algebra of events, preliminaries of sets; Definitions of Probability - classical, statistical, and axiomatic; theorems on probability, addition theorem and extension, Boole's inequality. (10 Hours)

Module 2:

Conditional probability, multiplication theorem of probability, independence of events, pairwise independent events, extended axiom of addition and axiom of continuity, Bayes' theorem and problems on Bayes' theorem. (10 Hours)

Module 3:

One - dimensional random variables - introduction, definition and examples; Distribution function (DF) - definition, properties; Discrete random variable - probability mass function (pmf), discrete DF and problems; Continuous random variables - probability density function (pdf), continuous DF and problems; transformation of one dimensional random variable. (20 Hours)

Module 4:

Two - dimensional random variables - definition, joint, marginal and conditional probability distribution functions of discrete and continuous random variables; Distribution function - definition and properties, marginal DF, conditional DF; independence of random variables, generalization to n-dimensional random variable. (20 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.
2. Ross, S. M. (2022). *A First Course in Probability*, 10^{th} Edition. Pearson Education Limited, London.

References:

1. Blitzstein, J. K. and Hwang, J. (2019). *Introduction to Probability*, 2^{nd} Edition. CRC Press, New York.
2. Grinstead, C. M. and Snell, J. L. (1997). *Introduction to Probability*. American Mathematical Soc.
3. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.
4. Spiegel, M. R., Schiller, J. J. and Srinivasan, R. A. (2013). *Schaum's Outline of Probability and Statistics*, 4^{th} Edition. McGraw-Hill Education, New York.
5. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New York.

24-810-0202 Probability Distributions

Credits (H/W for L-T-P) : 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Discuss various discrete distributions and properties	Understand
2.	Discuss various continuous distribution and properties	Understand
3.	Illustrate sampling distributions and interrelations	Analyse
4.	Demonstrate the fitting of distributions- binomial, Poisson, normal using Excel	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3				3	3		
CO2	3				3	3		
CO3			3		3	3	2	1
CO4	3		3		3	3	2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Discrete distributions: Uniform, Bernoulli, binomial, Poisson, geometric - mean, variance, mgf, pgf and important properties; Negative binomial, hyper-geometric - definition and properties. (15 Hours)

Module 2:

Standard distributions - continuous type: uniform, normal, exponential, gamma, beta (type I and type II) - mean, variance, mgf, pgf and important properties; Lognormal, Pareto and Cauchy - definition and properties. (15 Hours)

Module 3:

Sampling distributions, distribution of sample mean and variance; Chi-square, Students-t, F-distributions - their interrelations and properties. (15 Hours)

Module 4:

Generating random variables; Fitting of distributions - binomial, Poisson, normal - theory and practical illustrations using MS Excel. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2017). *Introductory Statistics*, 4^{th} Edition. Academic Press, India.

References:

1. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.

2. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New York.

3. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

24-810-0203 Probability Theory and Random Variables

Credits (H/W for L-T-P) : 3 (2-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Discuss the basic principles of probability including theorems on probability and use these principles in problem solving situations	Understand
2.	Demonstrate basic probability relations including conditional probabilities and Bayes' Law	Apply
3.	Employ the definitions of univariate and bivariate random variables	Apply
4.	Calculate the density and distribution function of a random variable	Analyse
5.	Differentiate the marginal density and distribution function from the joint density function and distribution function	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2			3	3	1	
CO2	3	1		2	3	3	1	
CO3		3		1	3	3		
CO4	3	2		1	3	3		
CO5	3	2		1	3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction, preliminaries of sets, random experiments, sample space, events and algebra of events; Definitions of probability – classical, statistical, and axiomatic; Theorems on probability - addition theorem and extension. (10 Hours)

Module 2:

Conditional probability, multiplication theorem of probability, independence of events, pairwise and mutual independent, Bayes' theorem and problems on Bayes' theorem. (10 Hours)

Module 3:

Random variables - introduction, definition and examples; Distribution function (DF) - definition, properties; Discrete random variable - probability mass function (pmf), discrete DF and problems; Continuous random variables - probability density function (pdf), continuous DF and problems. (20 Hours)

Module 4:

Definition, joint probability mass function, marginal probability mass function, conditional probability function; Distribution function - definition and properties, marginal DF; joint and marginal density function, conditional DF and conditional pdf, independence of random variables. (20 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Ross, S. M. (2022). *A First Course in Probability*, 10^{th} Edition. Pearson Education Limited, London.

References:

1. Spiegel, M. R., Schiller, J. J. and Srinivasan, R. A. (2013). *Schaum's Outline of Probability and Statistics*, 4^{th} Edition. McGraw-Hill Education, New York.

2. Spiegel, M. R., Schiller, J. and Srinivasan, R. (2000). *Theory and Problems of Probability and Statistics (Schaums Outlines)*, 4^{th} Edition. McGraw-Hill Education, New York.

3. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

4. Blitzstein, J. K. and Hwang, J. (2019). *Introduction to Probability*, 2^{nd} Edition. CRC Press, New York.

5. Grinstead, C. M.and Snell, J. L. (1997). *Introduction to probability*. American Mathematical Society.

Semester III

Semester Credit: 21 (Major: 4, Minor: 8, MDC: 3, VAC: 6); Cumulative Credit: 63								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0301	Statistical Methods	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0302	Statistical Inference	STAT Minor - DSC	None	3-0-2	4	50	50	100
24-810-0303	An Introduction to Statistical Methods	MDC	None	2-0-2	3	50	50	100

24-810-0301 Statistical Methods

Credits (H/W for L-T-P) : 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the concept of mathematical expectation and its various properties	Understand
2.	Discuss various generating functions such as PGF, MGF, CGF, CF and its importance	Understand
3.	Understand different modes of convergence	Understand
4.	Evaluate various probability bounds using law of large numbers	Interpret

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2		3	3		
CO2	3			2	3	3		
CO3	3		2		3	3		
CO4	3			2	3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Mathematical expectation - mathematical expectation of a random variable and functions of a random variable, properties of expectation, inequalities of moments, conditional expectation. (15 Hours)

Module 2:

Generating functions - probability generating function, moment generating function, cumulant generating function and characteristic function; properties of generating function, uniqueness and inversion theorems (without proof) along with applications. (15 Hours)

Module 3:

Modes of convergence - convergence in probability, convergence in almost sure, convergence in distribution, convergence in r^{th} mean. (15 Hours)

Module 4:

Chebychev's inequality, weak law of large numbers, strong law of large numbers, central limit theorems (without proof). (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Hogg, R.V., Mckean, J. and Craig, A.T. (2018). *Introduction to Mathematical Statistics*, 8^{th} Edition. Pearson, USA.

24-810-0302 Statistical Inference

Credits (H/W for L-T-P) : 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Apply various estimation and testing procedures to deal with real life problems	Apply
2.	Distinguish between point estimation and interval estimation	Analyse
3.	Apply various estimation and testing procedures to deal with real life problems	Apply
4.	Examine unbiasedness, consistency, efficiency, and sufficiency of estimators	Analyse
5.	Illustrate the testing of a statistical hypothesis, to draw valid conclusions	Analyse
6.	Apply large sample and small sample testing procedures and its applications	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2		1	1	2	2	1
CO2	2		2	1	2	3		
CO3	1	2			2	2		
CO4	1	2			3	3		1
CO5	2	1			3	3		2
CO6	2				2	2		2

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Estimation - point estimation; Properties of estimators - unbiasedness, consistency, efficiency, sufficiency; Methods of estimation - method of moments, maximum likelihood method; properties of moment estimator and maximum likelihood estimator, illustrations for different distributions. (15 Hours)

Module 2:

Interval estimation; Confidence interval (CI) - CI for mean of a normal population (3 cases), difference of mean for two normal populations (3 cases), for variance, proportion of success and difference in proportion of success of binomial population. (15 Hours)

Module 3:

Testing of hypothesis - statistical hypotheses, simple and composite hypotheses, two types of errors, significance level, p - value, power of a test, Neyman - Pearson lemma (without proof), most powerful tests. (15 Hours)

Module 4:

Large sample tests, small sample tests, t - test, chi - square test for variance, goodness of fit, independence of attributes. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2^{nd} Edition. Duxbury Advanced Series, USA.

2. Hogg, R.V., Mckean, J. and Craig, A.T. (2018). *Introduction to Mathematical Statistics*, 8^{th} Edition. Pearson, USA.

3. Wasserman, L. (2010). *All of Statistics: A Concise Course in Statistical Inference*, Springer, India.

24-810-0303 Introduction to Statistical Methods

Credits (H/W for L-T-P): 3 (2-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the concept of mathematical expectation and its various properties	Understand
2.	Discuss various generating functions such as PGF, MGF, CGF, CF, and their importance	Understand
3.	Understand different types of modes of convergence	Understand
4.	Evaluate various probability bounds using law of large numbers	Interpret

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2		3	3		
CO2	3			2	3	3		
CO3	3			2	3	3		
CO4	3		2		3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Mathematical expectation - mathematical expectation of a random variable and functions of a random variable, properties of expectation, conditional expectation, important Inequalities. (15 Hours)

Module 2:

Generating Functions - probability generating function, moment generating function, cumulant generating function and characteristic function, properties of generating function. (15 Hours)

Module 3:

Modes of convergence - convergence in probability, convergence in almost sure, convergence in distribution, convergence in r^{th} mean, interrelations. (15 Hours)

Module 4:

Chebychev's inequality, weak law of large numbers, strong law of large numbers, central limit theorems. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Hogg, R. V., McKean, J. W. and Craig, A. T. (2018). *Introduction to Mathematical Statistics*, 8^{th} Edition. Pearson, USA.

Semester IV

Semester Credit: 22 (Major: 16, SEC: 3, VAC: 3); Cumulative Credit: 85								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0401	Discrete Distributions	STAT Major - DSC	24-810-0201	3-0-2	4	50	50	100
24-810-0402	Continuous Distributions	STAT Major - DSC	24-810-0201	3-0-2	4	50	50	100
24-810-0403	Bivariate Data Analysis	STAT Major - DSC	24-810-0101	3-0-2	4	50	50	100
24-810-0404	Sampling Theory and Methods - I	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0405	Statistical Data Analysis Using R - I	SEC	None	1-0-4	3	50	50	100

24-810-0401 Discrete Distributions

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand various discrete distributions	Understand
2.	Demonstrate properties of random variables such as moments, generating functions etc	Apply
3.	Illustrate various applications of the discrete distributions	Analyse
4.	Demonstrate the fitting of distributions - binomial, Poisson	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2		3	3		
CO2	3		2		3	3		
CO3	3		2		3	3		
CO4	3		2		3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Degenerate distribution, uniform distribution on n points, Bernoulli distribution - definitions and examples, properties, transformations. (15 Hours)

Module 2:

Binomial distribution, Poisson distribution - properties, real life applications, additive property, approximation, characterizations, conditional distributions. (15 Hours)

Module 3:

Negative binomial distribution (Pascal or waiting time distribution), geometric distribution - properties, characterizations, real life applications, approximation. (15 Hours)

Module 4:

Hypergeometric distribution - definition, real life applications, approximation; fitting of binomial, Poisson distributions. (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.
2. Johnson, N. L., Kemp, A. W. and Kotz, S. (2005). *Univariate Discrete Distributions* (Volume 444), 3^{rd} Edition. John Wiley & Sons, New York.
3. Bhuyan, K. C. (2010). *Probability Distribution Theory And Statistical Inference*, New Central Book Agency (P) Limited, India.

24-810-0402 Continuous Distributions

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand various continuous distributions	Understand
2.	Demonstrate properties of random variables such as moments, generating functions etc	Apply
3.	Illustrate various applications of the continuous distributions	Analyse
4.	Demonstrate the fitting of normal distribution	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2		3	3		
CO2	3		2		3	3		
CO3	3		2		3	3		
CO4	3		2		3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Uniform and normal distributions - properties, characterizations, related distributions, approximations. (15 Hours)

Module 2:

Lognormal and Cauchy distributions - properties, related distributions, characterizations, applications. (15 Hours)

Module 3:

Rectangular, exponential, gamma, beta distributions - properties, real life applications, characterizations, related distributions. (15 Hours)

Module 4:

Weibull and Pareto, logistic, extreme value distributions - properties, related distributions, characterizations, applications. (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Johnson, N. L., Kotz, S. and Balakrishnan, N. (1995). *Continuous Univariate Distributions* (Volume 2), 2^{nd} Edition. John Wiley & Sons, New York.

3. Bhuyan, K. C. (2010). *Probability Distribution Theory and Statistical Inference*, New Central Book Agency (P) Limited, India.

24-810-0403 Bivariate Data Analysis

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand bivariate data and the concept of joint, marginal and conditional probability distributions	Understand
2.	Evaluate and interpret different types of correlation	Interpret
3.	Demonstrate the fundamental concept of linear and nonlinear models	Apply
4.	Analyse bivariate data and understand the concept of association between two variables	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3				3	3		
CO2		3	3		3	3	2	3
CO3	3		3		3	3	3	
CO4	3		3		3	3	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Bivariate data - definition, scatter diagram, joint, marginal and conditional distributions (discrete and continuous). (15 Hours)

Module 2:

Correlation - types of correlation, Karl Pearson's coefficient of correlation for grouped and ungrouped data and its properties, Spearman's rank correlation, ϕ coefficient, Cramers's V, Kendall's τ, measures using discordant and concordant pairs, point biserial correlation, interpretation of correlation coefficient, visualization of variables from different scales. (15 Hours)

Module 3:

Regression - lines of regression, regression coefficients, properties of regression coefficients, correlation versus regression; Curve fitting - principle of least squares, fitting of straight line, polynomial of n^{th} degree, exponential curve and power curves using the principle of least squares. (15 Hours)

Module 4:

Illustration with specific examples and numerical exercises using statistical packages. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

References:

1. Heumann, C. and Shalabh, M.S. (2016). *Introduction to Statistics and Data Analysis*, 1^{st} Edition. Springer, India.

2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2016). *Fundamentals of Statistics* (Volume 2), 4^{th} Edition. The World Press Private Limited, India.

3. Mukhopadhyay, P. (2019). *Applied Statistics*, 2^{nd} Edition. Books and Allied (P) Ltd, India.

24-810-0404 Sampling Theory and Methods - I

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Classify census, sampling and recognize the organization and execution of large sample surveys	Understand
2.	Practice the preparation of questionnaires	Apply
3.	Compute estimators for population parameters for quantitative and qualitative data	Apply
4.	Distinguish stratified, systematic and circular systematic sampling methods	Understand
5.	Compute sample estimators under cluster sampling	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2		2				
CO2	2			2				
CO3		2	2			2		
CO4		2	2			2		
CO5			2			2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Census and sampling, principal steps in sample survey, probability sampling, judgment sampling, organization and execution of large sample surveys, sampling and non - sampling errors, preparation of questionnaire, estimation of sample size. (10 Hours)

Module 2:

Simple random sampling with and without replacement - methods of collecting simple random samples, unbiased estimate of the population mean and population total, their variances and estimate of these variances, simple random sampling for proportions. (20 Hours)

Module 3:

Stratified random sampling - estimation of population mean and total, proportional and Neyman allocation of sample sizes, optimum allocation considering cost; Systematic sampling - linear and circular systematic sampling, comparison with simple random sampling. (20 Hours)

Module 4:

Cluster sampling: Clusters with equal sizes - estimation of the population mean and total, comparison with simple random sampling; Two stage cluster sampling - estimate of variance of population mean. (10 Hours)

Text Books:

1. Gupta, S.C. and Kapoor, V.K. (2014). *Fundamentals of Applied Statistics*, 4^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Bansal, A. (2017). *Survey Sampling*, Narosa Publishing House Pvt Ltd, India.

References:

1. Murthy, M.N. (1967). *Sampling Theory and Methods*, Statistical Publishing Society, Calcutta.

2. Mukhopadhyay, P. (2008). *Theory and Methods of Survey Sampling*, 2^{nd} Edition. PHI Learning Pvt Ltd, New Delhi.

3. Arnab, R. (2017). *Survey Sampling Theory and Applications*, Academic Press.

4. Singh, D. and Chaudhary, F.S. (2020). *Theory and Analysis of Sample Survey Designs*, 2^{nd} Edition. New Age International Private Limited, New Delhi.

5. Cochran, W. G. (2007). *Sampling Techniques*, 3^{rd} Edition. Wiley India Pvt. Ltd, India.

6. Sampath, S. (2005). *Sampling Theory and Methods*, 2^{nd} Edition. Alpha Science International Ltd, U. K.

24-810-0405 Statistical Data Analysis Using R - I

Credits (H/W for L-T-P): 3 (1-0-4)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	To understand the basics in R programming in terms of constructs, control statements, string functions	Understand
2.	Create matrices, arrays and lists using R	Create
3.	Import a variety of data formats into R using R Studio	Apply
4.	Apply critical programming language concepts such as data types, iteration, control structures, functions, and boolean operators by writing R programs and through examples	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1				2	2	3	3
CO2		2	2		1	1	3	3
CO3		3	3		2	2	3	3
CO4	3	1	1		2	2	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introducing to R - R Data Structures, installing and loading packages, setting up your working directory, downloading and importing data, working with missing data, extracting a subset of a dataframe, writing R scripts, adding comments and documentation, creating reports, Help functions in R, vectors, scalars, declarations, recycling, common vector operations, using all and any, vectorized operations, NA and NULL values, filtering, vectorized if - then else, vector equality, vector element names. (15 Hours)

Module 2:

Matrices, arrays and lists, creating matrices, matrix operations, applying functions to matrix rows and columns, adding and deleting rows and columns, vector/matrix distinction, avoiding dimension reduction, higher dimensional arrays; Lists – creating lists, general list operations, accessing list components and values, applying functions to lists, recursive lists. (15 Hours)

Module 3:

Creating dataframes, matrix like operations in frames, merging dataframes, applying functions to dataframes; Factors and tables, factors and levels, common functions used with factors, working with tables, other factors and related functions. (15 Hours)

Module 4:

Iteration - while loops, for loops, control statements, arithmetic and Boolean operators and values, default values for arguments, returning Boolean values, functions are objects, environment and scope issues, writing upstairs, recursion, replacement functions, tools for composing function code, math and simulations in R, creating graphs, customizing graphs, saving graphs to files, creating three dimensional plots. (15 Hours)

Text Books:

1. Matloff, N. (2011). *The Art of R Programming: A Tour of Statistical Software Design*, 1^{st} Edition. No Starch Press, US.

2. Crawley, M. J. (2012). *The R Book*, 2^{nd} Edition. John Wiley & Sons, U. K.

References:

1. Jones, O., Maillardet. R. and Robinson, A. (2014). *Introduction to Scientific Programming and Simulation Using R*, 2^{nd} Edition. Chapman & Hall/CRC, USA.

2. Lander, J. P. (2013). *R for Everyone: Advanced Analytics and Graphics*, 1^{st} Edition. Pearson Addison - Wesley Professional, USA.

3. Gardener, M. (2013). *Beginning R – The Statistical Programming Language*, John Wiley & Sons, USA.

4. Knell, R. J. (2014). *Introductory R: A Beginner's Guide to Data Visualisation, Statistical Analysis and Programming in R*, Robert Knell.

5. Wickham, H. and Grolemund, G. (2023). *R for Data Science*, 2^{nd} Edition. O'Reilly Media, Inc, U. S. (Available for free at http://r4ds.had.co.nz, http://r4ds.hadley.nz/.)

Semester V

Semester Credit: 23 (Major: 20, SEC: 3); Cumulative Credit: 108								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0501	Statistical Inference - I	STAT Major - DSC	24-810-0201/0202	3-0-2	4	50	50	100
24-810-0502	Statistical Quality Control	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0503	Operations Research - I	STAT Major - DSC	None	3-0-2	4	50	50	100
24-810-0504	Time Based Data and Index Numbers	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-05xx	Elective - I	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0508	Statistical Data Analysis Using Python	SEC	None	1-0-4	3	50	50	100
Elective - I (Choose any one course)								
24-810-0505	Machine Learning	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0506	Actuarial Statistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0507	Financial Statistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100

24-810-0501 Statistical Inference - I

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe various sampling distributions	Understand
2.	Relate various sampling distributions	Understand
3.	Differentiate desirable properties of good estimators	Analyse
4.	Differentiate the problem of point and interval estimators	Analyse
5.	Evaluate the estimators of parameters of various distributions by employing various approaches	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2			2		2	2
CO2	2	3						1
CO3			3	2	2	3	2	2
CO4		2		2	1	3	1	2
CO5		3		3	2	3	2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Population, sample, parameter and statistic, parameter space, sampling distributions, concept of random sampling and statistic, definition of sampling distribution, standard error, sampling distribution of the mean and variance of a sample arising from a normal distribution; Chi-square distribution - properties and applications; Student's t distribution - properties and applications; Snedecor's F distribution - properties and applications; Interrelationships between standard normal, Chi-square, t, and F distributions. (17 Hours)

Module 2:

Problems of statistical inference - estimate and estimator; point and interval estimation; Desirable properties of estimators - unbiasedness, consistency, efficiency and sufficiency. (15 Hours)

Module 3:

Interval estimation, confidence interval, confidence coefficient; Constructing confidence intervals - mean, variance, proportion of a population, difference of means and the difference of proportion of two populations. (13 Hours)

Module 4:

Methods of estimation: Method of moments – examples, properties of moment estimator (statement only); Method of maximum likelihood -properties of likelihood estimator (statement only); method of least-squares and minimum variance bound unbiased estimator. (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

2. Kale, B. K. (2005). *A First Course on Parametric Inference*, 2^{nd} Edition. Alpha Science International, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Mukhopadhaya, P. (2006). *Mathematical Statistics*, 3^{rd} Edition. Books and Allied Pvt. Ltd., Kolkata.

3. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2^{nd} Edition. Duxbury Advanced Series, USA.

24-810-0502 Statistical Quality Control

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Differentiate various types of control charts for variables	Apply
2.	Differentiate various types of control charts for attributes	Apply
3.	Analyse process and measurement system capability	Analyse
4.	Apply various types sampling plans for attributes and their measures of performance	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		2	3			2	2	2
CO2		2	3			2	2	
CO3			3			3	3	
CO4		2	1			2	2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Control charts for variables: Control charts for $\bar{x}$ and R - development and use of $\bar{x}$ and R, interpretation of $\bar{x}$ and R charts, effect of nonnormality on $\bar{x}$ and R charts, operating characteristic function, average run length for the $\bar{x}$ chart; Control charts for $\bar{x}$ and s - construction and operation of $\bar{x}$ and s charts, $\bar{x}$ and s control charts with variable sample size, s^2 control chart. (15 Hours)

Module 2:

Control charts for attributes: Control chart for fraction nonconforming, development and operation of the control chart, variable sample size, operating-characteristic function and average run length calculations; Control charts for nonconformities (defects) - procedures with constant sample size, procedures with variable sample size; choice between attributes and variables control charts. (15 Hours)

Module 3:

Process and measurement system capability analysis - process capability analysis using a histogram or a probability plot, process capability ratios, use and interpretation of C_p, process capability ratio for an off-center process, normality and the process capability ratio, process centering, confidence intervals and tests on process capability ratios, process capability analysis using a control chart, process capability analysis using designed experiments, process capability analysis with attribute data. (15 Hours)

Module 4:

Acceptance sampling plans - acceptance sampling by variables, sampling plans for a single specification limit with known and unknown variance, sampling plans with double specification limits, comparison of sampling plans by variable and attributes. (15 Hours)

Text Books:

1. Montgomery, D. C. (2019). *Introduction to Statistical Quality Control*, 8^{th} Edition. Wiley, New Jersey.

References:

1. Mittag, H. J. and Rinne, H. (1993). *Statistical Methods for Quality Assurance*, 2^{nd} Edition. CRC Press, USA Chapters 1, 3 and 4, 15.

2. Schilling, E. G. and Neubauer D. V. (2017). *Acceptance Sampling in Quality Control*, 3^{rd} Edition. CRC Press, USA.

3. Mitra, A. (2001). *Fundamentals of Quality Control and Improvement*, Pearson Education, Asia, Chapter 12 (relevant parts).

4. Duncan, A.J. (1986). *Quality control and Industrial Statistics*, 5^{th} Edition. Richard D. Irwin, Illinois.

5. Grant E. L. and Leavenworth, R. S. (2017) *Statistical Quality Control*, 7^{th} Edition. McGraw Hill Education, India.

6. Cho, Chin-Kuei (1987). *Quality Programming: Developing and Testing Software With Statistical Quality Control*. John Wiley & Sons, New Jersey.

24-810-0503 Operations Research - I

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Practice mathematical formulation of the linear programming problem	Apply
2.	Solve the linear programming problem using, graphical, simplex, big-M and two-phase methods	Apply
3.	Use the duality in LPP, its applications and dual simplex method	Apply
4.	Differentiate the methods of solving transportation and assignment problems	Analyse
5.	Distinguish basic components of network scheduling	Understand
6	Differentiate PERT and CPM	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3							
CO2		2				3		
CO3		2				2		
CO4	3					2		
CO5	2					2		
CO6		2		2				

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Linear programming problem (LPP) – mathematical formulation, graphical solution, simplex method and its computational procedure; Use of artificial variables – two phase and big-M methods. (20 Hours)

Module 2:

Duality in LPP, primal-dual problem, duality theorems, duality and simplex method, econometric interpretation of duality, dual simplex method. (15 Hours)

Module 3:

Transportation problem (TP) - LP formulation, initial basic feasible solution, test for optimality, degeneracy in TP, MODI and stepping stone methods, time minimization of TP; Assignment problem - solution methods and special cases. (15 Hours)

Module 4:

Network scheduling - basic components, critical path analysis, probability considerations in PERT. (10 Hours)

Text Books:

1. Swarup, Kanti, Gupta, P. K. and Mohan, Man. (2022). *Operations Research*, 20^{th} Edition. Sultan Chand & Sons, New Delhi.

References:

1. Hillier, F. S. and Lieberman, G. (2012). *Introduction to Operations Research*, 9^{th} Edition. McGraw-Hill Education, New Delhi.

2. Pundir, S. K. (2020). *Operations Research*. CBS Publishers & Distributors, New Delhi.

24-810-0504 Time Based Data and Index Numbers

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Calculate different types of index numbers and their constructions	Analyse
2.	Test index numbers using various tests	Analyse
3.	Apply the concepts of time series and obtain trend and seasonal indices	Apply
4.	Apply the time series method to predict the future of a problem in a concern	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	3			3	3	2	
CO2	3				3	3	2	
CO3		3		2	3	3	3	3
CO4		3		2	3	3	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction, components of time series, mathematical models for time series, uses of time series; Measurements of trend - graphic method, method of semi-averages, method of curve fitting by principle of least squares, growth curves and their fitting, moving average method, approximation to moving averages. (15 Hours)

Module 2:

Measurement of seasonal variations - method of simple averages, ratio to trend method, ratio to moving average method, link relative method, de-seasonalisation of data; Forecasting by smoothing methods - moving averages, weighted moving averages, exponential smoothing methods. (15 Hours)

Module 3:

Introduction & definition, basic problems involved in the construction of index numbers; Construction of index numbers - simple (unweighted) aggregate methods, weighted aggregate methods, average of price relatives, chain base method (chain indices); Criteria for a good index number - unit test, time reversal test, factor reversal test, circular test. (15 Hours)

Module 4:

Classification of index numbers, wholesale price index number, cost of living index number, consumer price indices (CPI) - Indian scenario, base shifting, splicing and deflating of index numbers, index of industrial production (IIP) - Indian scenario, index of agricultural production, uses of index numbers, limitations of index numbers. (15 Hours)

Text Books:

1. Gupta, S. C. and Kapoor, V. K. (2014). *Fundamentals of Applied Statistics*, 4^{th} Edition. Sultan Chand and Sons, New Delhi.

References:

1. Gupta, S. P. (2021). *Statistical Methods*, 46^{th} Edition. Sultan Chand and Sons, New Delhi.
2. Elhance, D. N., Elhance V. and Aggarwal B. M. (2018). *Fundamentals of Statistics*. Kitab Mahal, New Delhi.

24-810-0508 Statistical Data Analysis Using Python

Credits (H/W for L-T-P): 3 (1-0-4)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1	Students will demonstrate a solid understanding of Python fundamentals and statistical concepts	Understand
2	Students will be able to apply Python programming skills to manipulate and Analyse data using NumPy, Pandas, and other relevant libraries	Apply
3	Students will Analyse and interpret data using descriptive statistics, correlation, regression, and hypothesis testing	Analyse
4	Students will create Python-based solutions to statistical problems and effectively communicate findings	Create

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2	2		2	2	1	2
CO2		2			2	1		3
CO3	2	2	2		2	1	1	2
CO4	1	2	1	1	2	1		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to Python for statistics - overview of Python in statistical analysis, setting up Python environment (Anaconda, Jupyter Notebooks), introduction to Jupyter notebooks for interactive coding; Python basics - variables, assignments data types (integers, floats, strings), data structures, arithmetic operations, expressions, objects and classes, conditionals and loops. (15 Hours)

Module 2:

Data manipulation with NumPy and Pandas: NumPy basics - arrays and matrices, mathematical operations with arrays; Pandas fundamentals - series and data frames, data indexing and selection, loading and saving data with Pandas; data extraction, cleaning, integration, annotation, reduction, transformation, EDA, data pre-processing, handling quantitative and qualitative values. (20 Hours)

Module 3:

Descriptive statistics with Python: Measures of central tendency - mean, median, mode; Measures of dispersion - range, variance, standard deviation; frequency distributions and histograms; Visualization of descriptive statistics using Matplotlib & Seaborn - histograms, scatter plots, box plots, stem and leaf diagram, qq plot and summary statistics visualization, time series plots. (15 Hours)

Module 4:

Correlation and regression analysis: Calculating correlation coefficients - Pearson, Spearman; Simple linear regression - least squares method; Multiple linear regression - interpretation of coefficients; visualization of relationships using scatter plots, heat map and regression lines. (10 Hours)

Text Books:

1. Igual, L. and Seguí, S. (2017). *Introduction to Data Science - A Python Approach to Concepts, Techniques and Applications*. Springer, New York.

2. Raschka, S. (2019). *Python Machine Learning*, 3^{rd} Edition. Packt Publishing, United Kingdom.

References:

1. Summerfield, M. (2008). *Programming in Python 3: A Complete Introduction to the Python Language*, 1^{st} Edition. Addison Wesley, United Kingdom.

2. Park, A. (2021). *Python for Data Analysis: The Ultimate Guide for Beginners to Master Data Analysis and Analytics with Python Using Pandas, Numpy and Ipython*, 2^{nd} Edition. Eureka Online Ltd, United Kingdom.

Semester VI

Semester Credit: 23 (Major: 20, SEC: 3); Cumulative Credit: 131								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0601	Statistical Inference - II	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0602	Design and Analysis of Experiments - I	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0603	Multivariate Methods	STAT Major - DSC	24-810-0501	3-0-2	4	50	50	100
24-810-0604	Survival Analysis	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-06xx	Elective - II	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0608	Statistical Data Analysis Using R - II	SEC	24-810-0508	1-0-4	3	50	50	100
Elective - II (Choose any one course)								
24-810-0605	Introduction to Data Mining	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	3-0-2	4	50	50	100
24-810-0606	Econometrics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	0-2-0	4	50	50	100
24-810-0607	MOOC	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	0-2-0	4	-	100	100
Internship (Not counted as a course): 2 credits								

24-810-0601 Statistical Inference - II

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Differentiate hypothesis and statistical hypothesis	Understand
2.	List the basic concepts behind the statistical testing problem	Remember
3.	Solve the given statistical testing problem and arrive at a conclusion	Apply
4.	Differentiate the use of various tests based on chi - square distribution	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2		1	2		3	
CO2	3		3	2	2		2	
CO3			3	3	3			
CO4		2			1		3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Statistical hypothesis - simple and composite, null and alternative hypothesis; Two types of errors - type I error and type II error; level of significance, size and power of a test, critical region, power curve, power function and p - value. (15 Hours)

Module 2:

Large sample tests - testing the significance of a mean, testing the equality of two means, testing the significance of a proportion, testing the equality of two proportions, testing the significance of correlation coefficient, testing the significance of the difference between two correlation coefficients. (15 Hours)

Module 3:

Small sample tests: Tests based on Student's t distribution – test of significance of mean from a normal population, testing the equality of means of two normal populations, testing the significance of correlation coefficient, paired t test. (15 Hours)

Module 4:

Tests based on chi – square distribution - testing the goodness of fit, testing the independence of attributes, testing the significance of standard deviation of a normal population; Tests based on F distribution – testing the equality of variances of two normal populations. (15 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

2. Kale, B. K. (2005). *A First Course on Parametric Inference*, 2^{nd} Edition. Alpha Science International, India.

References:

1. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Mukhopadhaya, P. (2006). *Mathematical Statistics*, 3^{rd} Edition. Books and Allied Pvt. Ltd., Kolkata.

3. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2^{nd} Edition. Duxbury Advanced Series, USA.

24-810-0602 Design and Analysis of Experiments - I

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify the concepts of linear estimation, analysis of variance, two - way orthogonal and non-orthogonal data	Understand
2.	Identify one - way and two - way classifications	Understand
3.	Analyse one - way, two - way classifications, experiments with covariance and model adequacy checking procedures	Analyse
4.	Apply methods of analysing different types of basic designs of experiments and analysis of covariance	Apply
5.	Discuss factorial experiments and incomplete block designs	Understand
6	Apply methods of analyzing factorial experiments and incomplete block designs	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2							
CO2			3	2				
CO3		2	3	2				
CO4		2	3					
CO5	2		3	2				
CO6	2		2					

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Linear estimation, estimability of parametric functions; Analysis of variance – assumptions of ANOVA test, one - way and two - way classified data (with single observation per cell) and their analysis and estimation; analysis of two - way orthogonal data, analysis of non - orthogonal two - way data, analysis of fixed and random effects models. (20 Hours)

Module 2:

Model adequacy checking, contrasts and orthogonal contrasts, comparing pairwise treatment means, principles of experimentation; Design and analysis of CRD & RBD – fixed and random effects; missing values. (18 Hours)

Module 3:

Latin square design, missing plot technique, comparison of efficiency, Graeco - Latin square design, analysis of covariance with a single observation per cell. (12 Hours)

Module 4:

Basic concepts of factorial experiments, 2^2 and 2^3 factorial experiments, basic concepts of Incomplete block design, balanced incomplete block design. (10 Hours)

Text Books:

1. Montgomery, D C. (2019). *Design and Analysis of Experiments*, 10^{th} Edition. John Wiley & Sons.

2. Das, M.N. and Giri, N.C. (2017). *Design and Analysis of Experiments*, New Age Publishers, New Delhi.

References:

1. Gupta, S.C. and Kapoor, V.K. (2014). *Fundamentals of Applied Statistics*, 4^{th} Edition. Sultan Chand & Sons, New Delhi.

2. Joshy, D.D. (2020). *Linear Estimation and Design of Experiments*, 2^{nd} Edition. New Age International Pvt. Ltd, India.

24-810-0603 Multivariate Methods

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe various plots for multivariate data	Understand
2.	Find marginal and conditional distribution of multivariate distributions.	Evaluate
3.	Describe different multivariate distributions and its properties	Understand
4.	Analyse categorical data and make conclusion from it	Analyse
5.	Distinguish between partial and multiple correlation	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1		2			1	1	
CO2	1		2			1	1	
CO3	1		2			1	1	
CO4	1		2			1	1	
CO5	1		2			1	1	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Multivariate data visualization - mosaic plots, scatter plot matrix, bivariate qq - plots, spider web plots, DD Plots, parallel coordinate plots, trellis displays. (10 Hours)

Module 2:

Multivariate probability distribution - mean vector and covariance matrix, marginal and conditional distribution, ellipsoid of concentration; Standard multivariate probability distributions - multivariate normal, multinomial, Dirichlet distributions, their properties and related results. (20 Hours)

Module 3:

Analysis of categorical data - contingency table, independence and association of attributes, measure of association - odds ratio, Pearson's and Yule's measure. (15 Hours)

Module 4:

Descriptive measures on multivariate data - multiple correlations, partial correlation, relationship between higher order and lower order partial correlations, related problems and inequalities. (15 Hours)

Text Books:

1. Anderson, T. W. (2009). *An Introduction to Multivariate Statistical Analysis (Chapter-2)*, 3^{rd} Edition. John Wiley & Sons, India.

2. Johnson, R. A. and Wichern, D. W. (2023). *Applied Multivariate Statistical Analysis*, 6^{th} Edition. Pearson, London.

References:

1. Alan, A. (2007). *An Introduction to Categorical Data Analysis*, 2^{nd} Edition. John Wiley & Sons, New Jersey.

2. Hardle, W. and Simar, L. (2019). *Applied Multivariate Statistical Analysis*, 5^{th} Edition. Springer, Switzerland.

3. Kendall, M. G., & Alan, S. (1961). *The Advanced Theory of Statistics*. Vols. I (Ch. 15) and II (Ch26, 27). Charles Griffin.

4. Rao, C. R. (1974). *Linear Statistical Theory and its Applications*, (Chapter-4 & 8), Wiley Eastern.

5. Wilks, S.S. *Mathematical Statistics (Chapter 6)*. John Wiley.

24-810-0604 Survival Analysis

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the basic concepts and ideas of survival analysis	Understand
2.	Understand the statistical techniques for survival data	Understand
3.	Examine the properties and methods for standard survival time distributions	Analyse
4.	Estimate survival functions using parametric and non - parametric methods	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3			1	2	2		
CO2	2		1		3	1	2	
CO3	1				2	1		
CO4	2		2		1		1	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to survival analysis survivor function, hazard function, cumulative hazard function, density function and their relationships for both continuous and discrete survival times. (15 Hours)

Module 2:

Censoring - type 1 censoring, type 2 censoring, left and right censoring, interval censoring, progressive censoring; left Truncation, right truncation. (15 Hours)

Module 3:

Parametric survival models - normal distribution, exponential distribution, Weibull Distribution, log normal distribution, extreme value distribution, Gompertz distribution, basic properties. (15 Hours)

Module 4 :

Non - parametric estimation and graphical methods - Kaplan - Meier estimator, Nelson - Aalen estimator, and their variance estimators; log - rank test for distribution difference, graphical methods that combine nonparametric estimation. (15 Hours)

Text Books:

1. Klein, J. P. and Moeschberger, M.L. (2005). *Survival Analysis - Techniques for Censored and Truncated Data*, 2^{nd} Edition. Springer - Verlag New York Inc, Germany.

References:

1. Hosmer, D. W., Lemeshow, S., and May, S. (2008). *Applied Survival Analysis: Regression Modeling of Time - to - Event Data*, 2^{nd} edition. Wiley - Interscience, United Kingdom.

2. Collett, D. (2023). *Modelling Survival Data in Medical Research*, 4^{th} edition. Chapman and Hall/CRC, New York.

24-810-0608 Statistical Data Analysis Using R - II

Credits (H/W for L-T-P): 3 (1-0-4)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Analyse various measures of central tendency, dispersion, skewness, kurtosis and correlation by R	Analyse
2.	Visualize data attributes using ggplot2 and other R packages	Analyse
3.	Create documents, presentations, websites etc. using R	Create
4.	Apply the R programming from a statistical perspective	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	3	2		1	3	2	3
CO2		3	3		1	3	2	3
CO3		3	3		1	3	2	3
CO4		3	3	2	1	3	2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Measures of central tendency, measures of variability, skewness and kurtosis, summary functions, describe functions, and descriptive statistics by group, correlation. (15 Hours)

Module 2:

Scatter plots, box plots, scatter plots and box and whisker plots together, histograms; Messy data - renaming columns (variable names) , attaching / detaching; Tabulating data - constructing simple frequency tables, ordering factor variables. (15 Hours)

Module 3:

Using the ggplot2 package to visualize data - applying themes from ggthemes to refine and customize charts and graphs; building data graphics for dynamic reporting, writing SQL statements in R, using the Select, From, Where, Is, Like, Order By, Limit, Max, Min SQL functions, interfacing R to other languages, parallel R. (20 Hours)

Module 4:

R Markdown basics - text formatting, code chunks, YAML header, preview of notebooks, presentations, websites, and dashboards, basic statistics. (10 Hours)

Text Books:

1. Matloff, N. (2011). *The Art of R Programming: A Tour of Statistical Software Design*, 1^{st} Edition. No Starch Press, US.

2. Crawley, M. J. (2012). *The R Book*, 2^{nd} Edition. John Wiley & Sons, U. K.

References:

1. Wickham, H. and Grolemund, G. (2023). *R for Data Science*, 2^{nd} Edition. O'Reilly Media, Inc, U. S. (Available for free at http://r4ds.had.co.nz, http://r4ds.hadley.nz/.)

2. Lander, J. P. (2013). *R for Everyone: Advanced Analytics and Graphics*, 1^{st} Edition. Pearson Addison - Wesley Professional, USA

3. Gardener, M. (2013). *Beginning R – The Statistical Programming Language*, John Wiley & Sons, USA.

4. Knell, R. J. (2014). *Introductory R: A Beginner's Guide to Data Visualisation, Statistical Analysis and Programming in R*, Robert Knell.

List of Electives for V/VI Semesters

24-810-0505 Machine Learning

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the essential concepts and methods in Statistical Machine Learning	Understand
2.	Apply machine learning techniques, including linear regression, logistic regression, and support vector machines, to real-world problems	Apply
3.	Analyse the performance of machine learning models, including assessing bias-variance trade-offs, overfitting, and the impact of regularization	Analyse
4.	Develop and present solutions to real-world problems using a variety of machine learning techniques	Create

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		2			2	1	1	1
CO2	1	2			3	1	2	3
CO3	2	2	3		3			
CO4			3	1	3	1	2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Overview of machine learning and its applications, the distinction between supervised, unsupervised, and semi-supervised learning, simple and multiple linear regression, model fitting, parameter estimation, and hypothesis testing; Model assessment and selection - bias-variance trade-off and overfitting; cross-validation and its application in model selection, performance metrics for classification and regression tasks. (20 Hours)

Module 2:

Linear methods for classification: Logistic regression for binary classification; Multiclass classification using one-vs-rest and one-vs-one approaches; maximum likelihood estimation and decision boundaries, basis expansion; Regularization and Kernel Methods - Feature transformation and basis expansion techniques; regularization methods (L1, L2) for improving model robustness, kernel methods for nonlinear classification and regression. (20 Hours)

Module 3:

Support vector machines - maximum margin classifiers and support vector classification, nonlinear separation using kernel trick, soft - margin classification and handling outliers; Tree - based methods and boosting - decision tree construction and split criteria, ensemble learning with bagging and boosting, introduction to random forests and gradient boosting. (10 Hours)

Module 4:

Unsupervised learning - clustering algorithms (K-means, hierarchical clustering), density estimation with Gaussian mixture models (GMM), recursive feature elimination, principal component analysis (PCA) for dimensionality reduction. (10 Hours)

Text Books:

1. Alpaydin, E. (2020). *Introduction to Machine Learning*, 4^{th} Edition. MIT Press, USA.

2. Witten, D., James, G., Hastie, Trevor and Tibshirani, Robert. (2013). *An Introduction to Statistical Learning with Applications in R*, 1^{st} Edition. Springer, New York.

References :

1. Deisenroth, M. P., Faisal, A. A., and Ong, C. S. (2020). *Mathematics for Machine Learning*. Cambridge University Press, United Kingdom.

2. Hardt, M., & Recht, B. (2022). *Patterns, Predictions, and Actions: Foundations of Machine Learning*. Princeton University Press, US.

24-810-0506 Actuarial Statistics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Analyse the stochastic behaviour of the insurance industry	Analyse
2.	Evaluate the statistical methods for actuarial data	Evaluate
3.	Understand the actuarial present values or benefits in life insurance products	Understand
4.	Analyse the concept of annuities and reserves	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2			2	2		1
CO2	1	1						
CO3	2	1	2		2		2	
CO4	3	2			1		1	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Insurance business - introduction, insurance companies as business organizations, concept of risk - failure lifetime distributions and life tables, future lifetime random variable, curtate future lifetime, life tables. (15 hours)

Module 2:

Actuarial present values or benefit in life insurance products, compound interest and discount factor, benefit payable at the moment of death, benefit payable at the end of year of death – relation between these quantities. (15 hours)

Module 3:

Annuities - annuities certain, continuous life annuities, discrete life annuities, life annuities with monthly payments, premiums- Loss at issue random variable, fully continuous premiums, fully discrete premiums. (15 hours)

Module 4:

Reserves - fully continuous reserves, fully discrete reserves; Multiple life contracts - joint life status, last survivor status. (15 hours)

Text Books:

1. Desmukh S. R. (2009). *Actuarial Statistics - An Introduction Using R*, 3rd Edition. Universities Press (India) Private Ltd., Hyderabad.

References:

1. Promislow, S. D. (2006). *Fundamentals of Actuarial Mathematics*, John Wiley, Chapters 2-11 and 14.

2. Dickson, C. M. D. (2016). *Insurance Risk and Ruin*, 2nd Edition. Cambridge University Press, United Kingdom.

3. Bowers, N. L., Gerber, H. U., Hickman, J. C., Jones, D. A. And Nesbitt, C. J. (1997). *Actuarial Mathematics*, 2nd Edition. Society Of Actuaries, Illinois.

24-810-0507 Financial Statistics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Explain fundamental concepts of statistical terminology related to financial data analysis	Understand
2.	Identify suitable stochastic models for financial data	Analyse
3.	Understand the intricacies of the pricing derivatives and analyse them quantitatively	Understand
4.	Use the tools needed for option pricing	Application
5.	Analyse different option pricing models	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2		2		2	2	
CO2	1	2		2		2	2	
CO3	1	2		2		2	2	
CO4	1	2		2		2	2	
CO5	1	2		2		2	2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic concepts of probability theory - random variables, expectation and moments, skewness and kurtosois, random vectors, dependence, correlation, conditional probabilities; Stochastic processes in discrete time - binomial processes, general random walks, geometric random walks, binomial models with state dependent increments. (15 Hours)

Module 2:

Introduction to derivatives - forward contracts, spot price, forward price, future price; call and put options, zero-coupon bonds and discount bonds; Pricing Derivatives - arbitrage relations and perfect financial markets, pricing futures, put-call parity for European options, relationship between strike price and option price; Discrete time process - binomial model with period one. (15 Hours)

Module 3:

Tools needed for option pricing - continuous time process - geometric Brownian motion, Wiener process, stochastic integration and stochastic differential equations, stock price as a stochastic process, Ito's lemma. (15 Hours)

Module 4:

Black-Scholes option pricing model - Black-Scholes differential equation, Black-Scholes formula for European options; Hedging portfolios - delta, gamma and theta hedging; Binomial model for European options - Cox-Ross-Rubinstein approach to option pricing; Discrete dividends. (15 Hours)

Text Books:

1. Franke, J., Hardle, W. K. and Hafner, C. M. (2019). *Statistics of Financial Markets*, 5^{th} Edition. Springer, Switzerland.

References:

1. Steland, Ansgar (2012). *Financial Statistics and Mathematical Finance: Methods, Models and Applications*. Wiley, New Jersey.

2. Lindstrom E., Madsen, H., and Nielsen J. N. (2019). *Statistics for Finance*. CRC Press, India.

3. Elliott, R. J. and Kopp, P. E. (2004). *Mathematics of Financial Markets*, 2^{nd} edition, Springer, New York.

4. Stanley L. S. (2012). *A Course on Statistics for Finance*, 1^{st} Edition. CRC Press, Florida.

5. Shreve, S. E. (2004). *Stochastic Calculus for Finance I - The Binomial Asset Pricing Model*, Springer, New York.

6. Mishura, Y. (2016). *Financial Mathematics*, ISTE Press Ltd - Elsevier Inc, London.

24-810-0605 Introduction to Data Mining

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand basic ideas of data mining	Understand
2.	Analyse the tools in data mining in a statistical perspective	Analyse
3.	Explore data using visualization methods	Analyse
4.	Familiarize data preprocessing methods	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	1				2	1	
CO2		2				2		1
CO3		2				1		3
CO4		3				3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Data mining - what is data mining, motivating challenges, scalability, high dimensionality, heterogeneous and complex data, data ownership and distribution, non - traditional analysis, origin of data mining; Data mining tasks - predictive task, descriptive task, predictive modeling, association analysis, anamoly detection. (20 Hours)

Module 2:

Data - types of data, attributes and measurements, data quality, data pre - processing, dicsretization and binarization, variable transformation, measures of similarity and dissimilarity, proxy measures and examples. (15 Hours)

Module 3:

Exploring Data - summary statistics, visualization, OLAP and multidimensional data analysis, major tasks in data preprocessing, data cleaning, data integration, data reduction, data transformation, dimensionality reduction and pivoting. (10 Hours)

Module 4:

Data Preprocessing - classification, basic concepts and preliminaries, general approach to solve a classification problem, decision trees, model overfitting, model evaluation, methods for comparing classifiers. (15 Hours)

Text Books:

1. Han, J., Pei, J. and Tong, H. (2022). *Data Mining: Concepts and Techniques*, 4^{th} Edition. Morgan Kaufmann Publishers In, India.

References:

1. Tan, P.N., Steinbach, M., Karpatne A. and Kumar, V. (2021). *Introduction to Data Mining*, 2^{nd} Edition. Pearson, London.

24-810-0606 Econometrics

Credits (H/W for L-T-P): 4 (3-0-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the importance of the relation between econometric analysis and economic theory	Understand
2.	Analyse the simple and multiple linear regression models	Analyse
3.	Explain the auto - regressive and distributed lag models	Evaluate
4.	Develop simultaneous equation models to represent the interdependent relationship between variables	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2				2	2	
CO2	1	2				2	2	
CO3	1	2				2	2	
CO4	1	2				2	2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Nature of econometrics and economic data - definition of econometrics, steps in empirical economic analysis, econometric model, the role of measurement in economics; The structure of economic data - cross - sectional data, time series data, pooled cross - section data, panel data. (10 Hours)

Module 2:

Simple regression model: Two variable linear regression model - assumptions, estimation of parameters, tests of significance and properties of estimators; Functional forms of Regression models – log - linear models, semi - log models and reciprocal models, choice of functional form; The general linear model - review of assumptions, estimation and properties of estimators, unbiasedness, BLUEs and tests of significance of estimates, analysis of variance; Dummy variables - nature of dummy variables, use of dummy variables, errors in variables and its consequences. (20 Hours)

Module 3:

Auto - regressive and distributed lag models: introduction; Types of lag schemes - Koyck's lag model, Almon's lag scheme, partial adjustment and expectations models; Causality in economics – the Granger causality Test. (15 Hours)

Module 4:

Simultaneous equation models - specification, simultaneous bias, inconsistency of OLS estimators, the concept of identification, rank and order conditions for identification, indirect least squares, two stage least squares (without proof), problems. (15 Hours)

Text Books:

1. Johnston, J. (1996). *Econometric Methods*, 4^{th} Edition. McGraw - Hill Education, New York.

2. Gujarathi, D.N, Porter, D.C., and Gunasekar, S. (2017). *Basic Econometrics*, 5^{th} Edition. McGraw Hill Education, India.

References:

1. Maddala, G.S. and Lahiri, K. (2012). *Introduction to Econometrics*, 4^{th} Edition. John Wiley & Sons, New York.

2. Tintner, G. (2013). *Econometrics*, Literary Licensing LLC, US.

3. Wooldridge, J. M. (2022). *Introductory Econometrics: A Modern Approach*, 7^{th} Edition. Cengage Learning India Pvt. Ltd, India.

24-810-0607 MOOC

Credits (H/W for L-T-P): 4 (0-2-0)

Semester VII

Semester Credit: 22 (Major: 20, Seminar/Open ended labs/Online course: 2); Cumulative Credit: 155								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0701	Mathematical Methods for Statistics	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0702	Probability Theory	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0703	Family of Distributions	STAT Major - DSC	None	2-1-2	4	50	50	100
24-810-0704	Sampling Theory and Methods - II	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-07xx	Elective - III	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0708	Practical-I and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
Elective - III (Choose any one course)								
24-810-0705	Categorical Data Analysis	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0706	Population Dynamics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0707	Biostatistics	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100

24-810-0701 Mathematical Methods for Statistics

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Demonstrate an understanding of limits and continuity of various functions	Apply
2.	Evaluate the Riemann - Stieltjes integral and verify the conditions for the existence of the integrals.	Evaluate
3.	Distinguish between the concepts of sequence and series, and determine limits of sequences and convergence and approximate sums of series	Analyse
4.	Compute the partial and total derivatives and maxima and minima of multivariable function	Apply
5.	Solve systems of linear equations, diagonalize matrices and Characterize quadratic forms	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2				2	2		
CO2	1				2	2		
CO3	2				2	2		
CO4	2				2	2		
CO5	2				2	2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Riemann - Stieltjes integral - definition, properties and important theorems, Eulers summation formula, integrators of bounded variation, sufficient conditions for existence of Riemann - Stieltjes integrals, mean value theorems of Riemann - Stieltjes integrals. (12 Hours)

Module 2:

Sequences and series of functions - pointwise and uniform convergence, properties and theorems; Multivariable calculus - limit and continuity, total derivative, directional derivatives, differentiation of composite functions, Taylor's Theorem for a multivariable function, inverse and implicit functions, optima of a multivariable function, method of Lagrange multipliers. (18 Hours)

Module 3:

Matrices - rank of a matrix, elementary transformations of a matrix and properties, inverse of a matrix by elementary transformations; Generalized inverse matrices - definition and existence; solving linear equations, Moore - Penrose inverse, symmetric matrices, properties of generalized inverse. (12 Hours)

Module 4:

Quadratic forms - classification and its characteristic properties, canonical forms, gram matrices; characteristic roots and characteristic vectors of a matrix, nature of characteristic roots of some special types of matrices, algebraic and geometric multiplicity of characteristic roots, Cayley - Hamilton theorem, orthogonal and unitary reductions of quadratic forms, spectral decomposition of a matrix, singular value decomposition. (18 Hours)

Text Books:

1. Searle, S. R. and Khuri, A. I. (2017). *Matrix Algebra Useful for Statistics*, 2^{nd} Edition. Wiley, USA.
2. Khuri, A.T. (1993). *Advanced Calculus with Applications in Statistics*, 1^{st} Edition. John Wiley & Sons, Inc., USA, Chapters - 3 and 7.
3. Apostol, T.M. (1996). *Mathematical Analysis*, 2^{nd} Edition. Narosa Publishing House, New Delhi, Chapters - 6, 7, 9.
4. Shanti Narayan (1991). *A Textbook of matrices*, S. Chand & Company, New Delhi, Chapters - 3, 6, 7, 10, 11.
5. Searle, S.R. (1971). Linear models, John Wiley & Sons, New York, Chapter - 1.

References:

1. Gupta, S.L. and Gupta, N.R. (2003) *Principles of Real Analysis*, 2^{nd} Edition. Pearson Education, New Delhi.
2. Widder, D.V. (2020) *Advanced Calculus*, 2^{nd} Edition. PHI Learning Pvt. Ltd., New Delhi.
3. Nanda, S. and Saxena, V.P. (2022) *Real Analysis*, 1^{st} Edition. Allied Publishers Pvt. Ltd., India.
4. Graybill, F.A. (2001) *Introduction to Matrices with Applications in Statistics*, 2^{nd} Edition. Cengage Learning.
5. Rao, C. R. (2001) *Linear Statistical Inference and its Applications*, 2^{nd} Edition. Wiley Series, United States, Chapter 1b, 1c.

24-810-0702 Probability Theory

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify sigma fields and compute limits of a sequence of random variables	Remember
2.	Describe properties of probability measure and distribution function	Remember
3.	Define expectation and moments	Understand
4.	Compute moment inequalities using expectations	Apply
5.	Concepts of independence and its use in multiplication properties, zero-one laws	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1				3	3		
CO2	2		2		3	3		
CO3	2		1		3	3		
CO4	2		3		3	3		
CO5	1		2		3	3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Classes of sets, fields, sigma fields, minimal sigma field, Borel sigma field, sequence of sets, lim sup and lim inf of a sequence of sets, measure, probability measure, properties of measure, Caratheodory extension theorem (statement only), Lebesgue and Lebesgue - Steiltjes measures. Measurable functions, random variables, sequence of random variables, distribution function and properties, decomposition of distribution function, distribution function of vector random variables, correspondence theorem (statement only). (15 Hours)

Module 2:

Integration of a measurable function with respect to a measure, monotone convergence theorem, Fatou's lemma, dominated convergence theorem. Expectation properties, inequalities and moments. Basic inequality, Jenseon's inequality, Cr-inequality. Moment generating function, Characteristic function , uniqueness theorem, inversion theorem, Bochner's theorem (statement only). (15 Hours)

Module 3:

Convergence in distribution, Convergence in probability, almost sure convergence, rth mean and interrelations, Levy's continuity theorem (statement only), Borel 0-1 law, Kolmogrov 0-1 law (statement only), Helly-Bray Lemma and theorem, independence. (15 Hours)

Module 4:

Kolmogrov's inequality, Weak law of large numbers – Bernoulli's, Khinchin's, Markov's. Kolmogorov's strong law of large numbers; Central limit theorem – De Moviers, Lindeberg-Levy, Liapnov's, Lindberg-Feller's theorems. (15 Hours)

Text Books:

1. Bhat, B.R. (2011). *Modern Probability Theory*, 2^{nd} Edition. Wiley Eastern, New Jersey, Chapters 1, 2, 3, 4, 5, 6, 9.

2. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Basu, A.K. (2012). *Measure Theory and Probability*, 2^{nd} Edition. PHI Learning Pvt. Ltd., New Delhi.

2. Billingsley, P. (2012) *Probability and Measure*, 3^{rd} Edition. Wiley Series, United States.

3. Bartle, R. G. (2010), *A Modern Theory of Integration*. American Mathematical Society, India.

4. Feller, W. (1991) *An Introduction to Probability Theory and Its Applications*, 3^{rd} Edition. Wiley India Pvt. Ltd, India.

5. Laha, R.G. and Rohatgi, V.K. (2020) *Probability theory*, Dover Publications Inc., New York.

6. Loeve, M. (1977) *Probability Theory*, 4^{th} Edition, Springer - Verlag, New York.

7. Rao, C. R. (2009). *Linear Statistical Inference and its Applications*, 2^{nd} Edition. John Wiley & Sons, New Delhi.

24-810-0703 Family of Distributions

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe and employ various statistical concepts to study the discrete distributions	Apply
2.	Describe and employ various statistical concepts to study the discrete distributions	Apply
3.	Describe properties of bivariate continuous exponential Distributions	Understand
4.	Illustrate characterization properties of the bivariate exponential	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2				3	3		
CO2	2		2		3	3		
CO3	2		3	3	3	3		2
CO4	3		2	3	3	3		3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Discrete Distributions: Modified power series family - properties, moment generating functions, recurrence relations for raw, central and factorial moments, recurrence relation for cumulants, binomial, negative binomial, logarithmic series and Lagrangian distributions as special cases of the results from modified power series family. (15 Hours)

Module 2:

Continuous distribution: Pearson family – identifications of the different types, beta, gamma, Pareto and normal as special cases of the Pearson family; exponential family of distributions, compound, truncated and mixture distributions - Lindley distribution; transformation of random variables. (15 Hours)

Module 3:

Sampling distributions: sampling distributions of the mean and variance from normal population, independence of mean and variance, chi - square, Student's - t and F distribution and their non - central forms, order statistics and their distributions, conditional distribution of order statistics, distribution of sample range. (15 Hours)

Module 4:

Bivariate distributions: multinominal, bivariate normal, bivariate exponential distribution of Gumbel, Marshall and Olkin and Block and Basu, Dirichlet distribution. (15 Hours)

Text Books:

1. Rohatgi, V.K. (1976). *An Introduction to Probability Theory and Mathematical Statistics*, John Wiley and Sons, New York.

2. Arnold, B.C., Balakrishnan, N. and Nagaraja, H.N. (2008). *A First Course in Order Statistics*. Society for Industrial and Applied Mathematics, United States of America.

3. Galambos, J. and Kotz, S. (2006). *Characterizations of Probability Distributions.: A Unified Approach with an Emphasis on Exponential and Related Models* (Vol. 675). Springer, Heidelberg.

4. Ord, J.K. (1972). *Families of Frequency Distributions*. Griffin's Statistical Monographs & Courses, London.

References:

1. Johnson, N. L., Kemp, A. W. and Kotz, S. (2005). *Univariate Discrete Distributions* (Volume 444), 3^{rd} Edition. John Wiley & Sons, New York.

2. Johnson, N. L., Kotz, S. and Balakrishnan, N. (1995). *Continuous Univariate Distributions* (Volume 2), 2^{nd} Edition. John Wiley & Sons, New York.

24-810-0704 Sampling Theory and Methods - II

Credits (H/W for L-T-P): 4 (2-1-2)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Classify the notion of sampling under ratio and regression methods	Understand
2.	Compute sample estimators for the population parameters under ratio and regression methods	Apply
3.	Compute estimators for population parameters under PPSWR and PPSWOR	Apply
4.	Employ two - stage sampling with equal and unequal sizes and double sampling	Apply
5.	Compute estimators when errors, non - responses present and under adaptive sampling	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	2					
CO2	2			2				
CO3						2		
CO4		2		2		2		
CO5	3	2		2				
CO6	2				2			

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to SRS, stratified, systematic and cluster sampling; Ratio estimator - optimum property of ratio estimator, unbiased ratio type estimator; Difference estimator and regression estimator - difference estimator, regression estimator, comparison of regression estimator with mean per unit and ratio estimator, regression estimator in stratified random sampling. (20 Hours)

Module 2:

PPSWR - estimation of population mean and total, selection of a PPSWR sample; PPSWOR - properties of a sampling design, Horvitz - Thomson, Yates - Grundy, estimators; Midzuno - Sen - Lahiri, Des Raj, Murthy sampling strategies. (18 Hours)

Module 3:

Multistage sampling - subsampling with units of equal sizes, optimum sampling, three stage sampling, subsampling with units of unequal sizes; Multiphase sampling - double sampling for difference, ratio and regression estimations. (12 Hours)

Module 4:

Errors in surveys - effect of unit non - response in the estimate, procedures for unit non - response; quota sampling, network sampling; Adaptive sampling - introduction and estimators under adaptive sampling. (10 Hours)

Text Books:

1. Cochran, W. G. (2007). *Sampling Techniques*, 3^{rd} Edition. Wiley India Pvt. Ltd, India.
2. Mukhopadhyay, P. (2008). *Theory and Methods of Survey Sampling*, 2^{nd} Edition. PHI Learning Pvt Ltd, New Delhi.
3. Bansal, A. (2017). *Survey Sampling*, Narosa Publishing House Pvt Ltd, India.

References:

1. Arnab, R. (2017). *Survey Sampling Theory and Applications*, Academic Press.
2. Sampath, S. (2005). *Sampling Theory and Methods*, 2^{nd} Edition. Alpha Science International Ltd, U. K.
3. Murthy, M.N. (1967). *Sampling Theory and Methods*, Statistical Publishing Society, Calcutta.
4. Singh, D. and Chaudhary, F.S. (2020). *Theory and Analysis of Sample Survey Designs*, 2^{nd} Edition. New Age International Private Limited, New Delhi.

24-810-0708 Practical-I and Viva Voce

Credits (H/W for L-T-P): 2 (0-0-4)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Apply the different mathematical methods using R software	Apply
2.	Apply the different sampling methods for designing and selecting a sample from a population	Apply
3.	Apply the methods of generating random numbers from different probability distributions and its goodness-of-fit using R software	Apply
4.	Formulate and solve problems which involve different probability distributions	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	3	3			3		3
CO2	2	2	3			3		3
CO3	2	1	2			3		3
CO4	2	2	1			3		3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Practicals based on topics covered in

- 24-810-0701 - Mathematical Methods for Statistics (15 Hours)
- 24-810-0703 - Family of Distributions (15 Hours)
- 24-810-0704 - Sampling Theory and Methods (15 Hours)
- 24-810-0705/06/07 - Elective Course (15 Hours)

Semester VIII

Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
B.Sc (Honours) in Statistics								
Semester Credit: 22 (Major: 20; seminar/open ended labs/online course: 2); Cumulative Credit: 177								
						CE	ES	Total
24-810-0801	Theory of Estimation	STAT Major - DSC	24-810-0703	2-1-2	4	50	50	100
24-810-0802	Stochastic Processes	STAT Major - DSC	24-810-0702	2-1-2	4	50	50	100
24-810-0803	Advanced Techniques for Data Analysis	STAT Major - DSC, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0804	Mini Project	STAT Major - DSC	None	0-4-0	4	50	50[b]	100
24-810-08xx	Elective - IV	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0808	Practical-II and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
Elective - IV (Choose any one course)								
24-810-0805	Reliability Modelling and Analysis	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0806	Introduction to Information Theory	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
24-810-0807	Statistical Analysis of Clinical Trials	STAT Major - DSE, STAT Minor - DSE, STAT Disci - DSE	None	2-1-2	4	50	50	100
Exit with B.Sc. (Honours) in Statistics (Total credits = 177)								
B.Sc (Honours with Research) in Statistics								
24-810-0801	Theory of Estimation	STAT Major - DSC	24-810-0703	2-1-2	4	50	50	100
24-810-0802	Stochastic Processes	STAT Major - DSC	24-810-0702	2-1-2	4	50	50	100
24-810-0808	Practical-II and Viva Voce	STAT Major - DSC	None	0-0-4	2	50	50[a]	100
24-810-0809	Project	STAT Major - DSC	None	0-12-0	12	50	50[b]	100
Exit with B.Sc. (Honours with Research) in Statistics (Total credits = 177).								

24-810-0801 Theory of Estimation

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Verify the desirable properties of good estimators	Evaluate
2.	Relate complete sufficient statistic, Rao-Blackwell theorem and Lehmann-Scheffe theorem.	Analyse
3.	Relate Cramer-Rao, Chapmann-Robbin's and Bhattacharya bounds	Analyse
4.	Compute estimator of parameter or parameters of any given distribution using various methods	Apply
5.	Compare classical inference and Bayesian inference	Analyse
6.	Evaluate Bayes and minimax estimator of parameters of any given distribution	Evaluate
7.	Illustrate Metropolis-Hasting algorithm, Gibbs sampler and MCMC method	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	2	1		2	3	2
CO2	3	1	1			3	3	
CO3	3	1	1			3	3	
CO4	2	2				3		
CO5	3					3	3	
CO6	3	3	2			3	2	
CO7	2	2				3		3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Problem of point estimation: Unbiasedness - bias and MSE of an estimator; Consistency (weak, strong and squared error consistency) - marginal and joint consistent estimators, invariance property of consistent estimator, CAN estimator, BAN estimator; Sufficiency - likelihood equivalence, minimal sufficiency and completeness, factorization theorem; exponential family, Pitman family, ancillary statistic and Basu's Theorem, equivariance and Pitman estimators. (18 Hours)

Module 2:

Fisher information measure and its properties, Fisher information matrix, lower bound to the variance of an unbiased estimator, Cramer - Rao, Chapman - Robbin's and Bhattacharya bounds, UMVUE estimators and their characterizations, Rao - Blackwell theorem, Lehmann - Scheffe theorem, UMVUE estimation of parametric functions from standard distributions, BLUE of parametric functions, efficiency. (14 Hours)

Module 3:

Methods of estimation - methods of moments, method of maximum likelihood, method of minimum chi-square and modified minimum chi - square, method of least squares, properties of maximum likelihood estimators, Cramer - Huzurbazar theorem; Likelihood equation - multiple roots, iterative methods, E.M. algorithm. (15 Hours)

Module 4:

Basic elements of Bayesian inference, loss function, prior distribution, posterior distributions, Bayes risk, Bayes principle, Bayes estimators, minimax estimators, Bayes theorem, Metropolis - Hastings algorithm, Gibbs sampler, MCMC method. (13 Hours)

Text Books:

1. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.
2. Rajagopalan, M. and Dhanavanthan, P. (2012). *Statistical Inference*. PHI Learning Private Limited, New Delhi.
3. Kale, B. K. (2005). *A First Course on Parametric Inference*, 2^{nd} Edition. Alpha Science International, India.

References:

1. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2^{nd} Edition. Duxbury Advanced Series, USA.
2. Rao, C. R. (2009). *Linear Statistical Inference and its Applications*, 2^{nd} Edition. John Wiley & Sons, New Delhi.
3. Mukhopadhay, P. (2006). *Mathematical Statistics*, 3^{rd} Edition. Books and Allied Pvt. Ltd., Kolkata.
4. Robert C. P. and Casella, G. (2004). *Monte Carlo Statistical Methods*, 2^{nd} Edition. Springer, New York.
5. Lehmann, E. L. and Casella, G. (1998). *Theory of Point Estimation*, 2^{nd} Edition, Springer, New York.

24-810-0802 Stochastic Processes

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the classifications of random processes and concepts such as strict stationarity, wide-sense stationary and ergodicity	Understand
2.	Classify the states of a Markov chain and apply ergodic theorem for finding limiting distributions on states	Analyse
3.	Apply Poisson, birth-death, renewal processes and Brownian motion	Apply
4.	Describe and use the recurrence relation for generation sizes in a branching process and determine the probability of ultimate extinction	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	3			3	3	2	
CO2	2	2	2	1	3	3	1	
CO3		3			2	3	3	3
CO4	3	3			2	3	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Stochastic process, stationary process, Markov process, martingales; Markov chains - definition, examples and classification, discrete renewal equation and basic limit theorem, absorption probabilities, criteria for recurrence. (25 Hours)

Module 2:

Continuous time Markov chains, examples, general pure birth process, Poisson process, birth and death process, finite state continuous time Markov chains, applications to queuing models. (15 Hours)

Module 3:

Galton-Watson branching processes, generating function, extinction probabilities, continuous time branching processes, extinction probabilities, branching processes with general variable life time. (10 Hours)

Module 4:

Renewal equation, renewal theorem, applications, generalizations and variations of renewal processes, applications of renewal theory, Brownian motion. (10 Hours)

Text Books:

1. Karlin, S. and Taylor, H. M. (1975). *A First Course in Stochastic Processes*, 2^{nd} Edition. Academic Press, United States. Relevant sections of Chapters 1, 2, 3, 4, 5 and 8.

2. Medhi, J. (2020). *Stochastic Processes*, 5^{th} Edition. New Age International Publishers, New Delhi.

3. Bhat, B. R. (2021). *Stochastic Models Analysis and Applications*, 2^{nd} Edition. New Age International, New Delhi.

References:

1. Cinlar, E. (1975). *Introduction to Stochastic Processes*. Dover Publications Inc., New York.

2. Ross, S. M. (1995). *Stochastic Processes*, 2^{nd} Edition. John Wiley & Sons, New Jersey.

3. Basu, A. K. (2003). *Introduction to Stochastic Process*, Alpha Science International Ltd., United Kingdom.

4. Kulkarni, V. G. (2011). *Introduction to Modeling and Analysis of Stochastic Systems*, 2^{nd} Edition, Springer, New York.

24-810-0803 Advanced Techniques for Data Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand longitudinal data and its analysis	Understand
2.	Apply regression techniques for longitudinal data	Apply
3.	Employ various data resampling techniques	Analyse
4.	Understand the analysis of missing data and analyse various methods for the same	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2		2	1			
CO2		1			1			2
CO3		2			3	3		3
CO4	3	1		1		2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction - longitudinal studies; Design considerations - bias, efficiency, sample size calculations; Exploring longitudinal data - graphical representation of longitudinal data, fitting smooth curves to longitudinal data, exploring correlation structure, general linear models for longitudinal data. (15 Hours)

Module 2:

Longitudinal regression - cohort vs longitudinal effect, robust estimation, weighted least-squares, robust standard error estimation; Parametric estimation - ML and REML; marginal, subject specific and transition models for continuous, binary and count outcomes, concept of GEE. (15 Hours)

Module 3:

Resampling techniques - permutation tests, introduction to jackknife and bootstrap methods for estimating bias, standard error and distribution function based on iid random variables, standard examples of bootstrap confidence intervals. (15 Hours)

Module 4:

Informative or non-informative missingness, MCAR, MAR and MNAR, complete case / available case estimation mean imputation, hot and cold deck imputation, MICE. EM & MCEM algorithms and data augmentation techniques. (15 Hours)

Text Books:

1. Diggle, P. J., Heagerty, P. J., Liang, K. Y. and Zeger, S. L. (2002). *Analysis of Longitudinal Data*, 2^{nd} Edition. Oxford University Press, London.

2. Efron, B. (1982). *The Jackknife, the Bootstrap, and Other Resampling Plans*. Society for Industrial and Applied Mathematics, Philadelphia.

3. Faraway, J. J. (2009). *Linear Models with R*. CRC, London.

4. Little, R. and Rubin, D. (2019). *Statistical Analysis with Missing Data*, 3^{rd} Edition. Wiley, New Jersey.

References:

1. Fitzmaurice, G., Laird, N. and Ware, J. *Applied Longitudinal Analysis*, 2^{nd} Edition. John Wiley & Sons, New Jersey.

2. Crowder, M. J. and Hand, D. J. (1990). *Analysis of Repeated Measures*, 1^{st} Edition. Chapman and Hall CRC Press, London.

3. Hand, D. and Crowder, M. (1996). *Practical Longitudinal Data Analysis*, 1^{st} Edition. Chapman and Hall CRC Press, London.

4. Lindsey, J. K. (1999). *Models for Repeated Measurements*, 2^{nd} Edition. Oxford University Press, London.

5. McCullagh, P. and Nelder, J. A. (1989). *Generalized Linear Models*, 2^{nd} Edition. Chapman and Hall CRC Press, London.

6. Weiss, R. E. (2005). *Modeling Longitudinal Data*, 1^{st} Edition. Springer, New York.

7. Enders C. K. (2022). *Applied Missing Data Analysis*, 2^{nd} Edition. Guilford Press, New York.

8. McLachlan G. J. and Krishnan T. (2007). *The EM Algorithm and Extensions*, 2^{nd} Edition, Wiley, New Jersey.

9. Efron B. and Tibshirani, R. J. (1994). *An Introduction to Bootstrap*, 1^{st} Edition. Chapman and Hall CRC Press, London.

24-810-0804 Mini Project

Credits (H/W for L-T-P): 4 (0-4-0)

24-810-0809 Project

Credits (H/W for L-T-P): 12 (0-12-0)

24-810-0808 Practical-II and Viva Voce

Credits (H/W for L-T-P): 2 (0-0-4)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand various tools using a programming software	Understand
2.	Apply different statistical inference problems using real data sets and interpretation of the results	Analyse
3.	Formulate and solve problems which involve setting up stochastic models	Evaluate
4.	Apply topics related to the chosen Elective paper using real data sets and interpretation of the results	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2		3		3	3		3
CO2		3			3	3		3
CO3		3			3	3	2	3
CO4		3			3	3	2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Practicals based on topics covered in

- 24-810-0801 - Theory of Estimation (15 Hours)
- 24-810-0803 - Advanced Techniques in Data Analysis (15 Hours)
- 24-810-0804 - Stochastic Processes (15 Hours)
- 24-810-0805/06/07 - Elective Course (15 Hours)

Semester IX

Semester Credit: 22-24 (Major: 20, Online Course: 2-4); Cumulative Credit: 199-201								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-0901	Testing of Hypothesis	STAT Major - DSC	24-810-0801	2-1-2	4	50	50	100
24-810-0902	Multivariate Analysis	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	24-810-0302 (To choose as DSE)	2-1-2	4	50	50	100
24-810-0903	Applied Regression Analysis	STAT Major - DSC, STAT Minor - DSC, STAT Disci - DSE	24-810-0302 (To choose as DSE)	2-1-2	4	50	50	100
24-810-0904	Design and Analysis of Experiments-II	STAT Major - DSC	24-810-0801	2-1-2	4	50	50	100
24-810-09xx	Elective - XIII	STAT Major - DSE	24-810-0503	2-1-2	4	50	50	100
24-810-0908	MOOC (2-4 credits)[c]	STAT Major - DSE	None	0-2-0	2-4	-	100	100
Elective - V (Choose any one course)								
24-810-0905	Operations Research - II	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0906	Reliability Engineering	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100
24-810-0907	Applications of Integral Transforms	STAT Major - DSE	24-810-0702	2-1-2	4	50	50	100

24-810-0901 Testing of Hypothesis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1	Identify the given statistical testing problem	Evaluate
2	Evaluate MP and UMP tests corresponding to any given testing problem	Evaluate
3	Relate confidence interval estimation and testing of hypothesis	Analyse
4	Compute shortest confidence interval for parameter/s of any given distribution using different methods	Apply
5	Formulate LR test corresponding to any given testing problem	Evaluate
6	Construct SPRT corresponding to any given testing problem	Evaluate
7	Examine the non-parametric alternatives for each parametric tests	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	3	3		3	2	
CO2	2	2	1			3		
CO3	3	2		1	2	2		
CO4	2					2	3	3
CO5	2	1	2	3	2	3	2	
CO6	3	2			1	2		
CO7	2							

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Review of basic elements of testing of hypothesis, randomized and non- randomized tests, most powerful (MP) test, Neyman-Pearson lemma and its generalization, monotone likelihood ratio (MLR) property, uniformly most powerful (UMP) tests, unbiased and uniformly most powerful unbiased (UMPU) tests with examples, α-similar tests, tests with Neyman structure, locally most powerful (LMP) tests. (17 Hours)

Module 2:

Confidence interval estimation, relationship between confidence interval estimation and testing of hypothesis, UMA and UMAU confidence intervals, shortest confidence intervals, construction of confidence intervals using pivots, large sample confidence interval based on maximum likelihood estimator, central limit theorem and Chebyshev's inequality; Bayesian credible regions. (16 Hours)

Module 3:

Likelihood ratio tests and their properties, testing mean and variance of a normal population, testing equality of means and variances of two normal populations, sequential probability ratio test (SPRT), construction of SPRT with examples, properties of SPRT. (13 Hours)

Module 4:

Non-parametric inference: Goodness of fit tests - chi square test and Kolmogorov- Smirnov test for one and two sample problems, sign test, signed rank test, Wald-Wolfowitz run test, median test, Man-Whitney U-test, non-parametric confidence intervals, bootstrapping confidence intervals, P-P plot and Q-Q plot, Kendall's tau. (14 Hours)

Text Books:

1. Lehmann, E. L. and Romano, J. P. (2022). *Testing Statistical Hypothesis*, 4^{th} Edition. Springer, Switzerland.

2. Wald, A. (2013). *Sequential Analysis*. Dover Publications, New York.

3. Gibbons, J. D. and Chakraborti, S. (2021). *Nonparametric Statistical Inference*, 6^{th} Edition. CRC Press, London.

4. Rohatgi, V. K. and Saleh, A. M. E. (2015). *An Introduction to Probability and Statistics*, 3^{rd} Edition. John Wiley & Sons, India.

References:

1. Kale, B. K. (2005). *A First Course on Parametric Inference*, 2^{nd} Edition. Alpha Science International, India.

2. Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12^{th} Edition. Sultan Chand & Sons, New Delhi.

3. Mukhopadhay, P. (2006). *Mathematical Statistics*, 3^{rd} Edition. Books and Allied Pvt. Ltd., Kolkata.

4. Casella, G. and Berger, R. L. (2002). *Statistical Inference*, 2^{nd} Edition. Duxbury Advanced Series, USA.

5. Dixit, U. J. (2016). *Examples in Parametric Inference with R*, 1^{st} Edition. Springer, Singapore.

24-810-0902 Multivariate Analysis

Credits (H/W for L-T-P): 4 (2-1-2)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe random vectors and their properties	Understand
2	Discuss the multivariate normal distribution and its properties	Understand
3	Understand the concept of Wishart distribution, distributions of simple, partial and multiple correlations and T^2 and D^2 statistics.	Understand
4	Identify various classification methods for multivariate data and cluster analysis.	Analyse
5	Explain principal component analysis and factor analysis	Evaluate
6	Identify canonical variables and quantify canonical correlation	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1	2	2				1	
CO2		2	2					
CO3		2	2					
CO4	2		2				2	
CO5	2		2				2	
CO6	2		2				2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Multivariate data, preliminary analysis, notion of multivariate distributions, multivariate normal distribution, marginal and conditional distributions, characteristic function, estimation of mean vector and covariance matrix, Wishart distribution and its properties, distribution of simple, partial and multiple correlations based on samples from normal population. (15 hours)

Module 2:

Hotelling's T^2 and Mahalanobis D^2 statistics, properties of T^2 and D^2, multivariate Fisher-Behren's problem, testing independence of sets of variates, testing equality of covariance matrices and means, sphericity tests, testing the hypothesis that a covariance matrix equal to given matrix, mean and covariance equal to a given vector and given matrix. (15 hours)

Module 3:

Classification problem - standards of good classification, procedures of classification into one of two populations with known probability distributions, classification into one of two known multivariate normal populations, classification into one of several populations; Clustering of observations - hierarchical clustering for continuous and categorical data, different choices of proximity measures, agglomerative and divisive algorithms, K-means clustering optimum choice of the number of clusters. (18 hours)

Module 4:

Principal component analysis - definition, properties and ML estimation, canonical variables, canonical correlation; Factor analysis - the orthogonal factor model, estimation of factor loading, factor rotation, estimation of factor scores, interpretation of factor analysis, multidimensional scaling. (12 hours)

Text Books:

1. Anderson, T. W. (2003). *An Introduction to Multivariate Statistical Analysis*, 3^{rd} Edition. Wiley, India.

2. Johnson, R. A. and Wichern, D. W. (2015). *Applied Multivariate Statistical Analysis*, 6^{th} Edition. Pearson, India.

References:

1. Everitt, B. and Hothorn, T. (2011). *An Introduction to Applied Multivariate Analysis with R*, 1^{st} Edition. Springer, New York.

2. Rao, C. R. (2009). *Linear Statistical Inference and its Applications*, 2^{nd} Edition. John Wiley & Sons, New Delhi.

3. Rencher, A. C. and Christensen, W. F. (2012). *Methods of Multivariate Analysis*, 3^{rd} Edition. John Wiley & Sons, India.

24-810-0903 Applied Regression Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify a linear and nonlinear regression problem	Apply
2.	Model a data using an appropriate regression model	Analyse
3.	Identify and interpret a regression model	Understand
4.	Examine model diagnostics	Analyse
5.	Identify a non parametric regression problem	Analyse
6	Apply non parametric regression techniques	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		2						
CO2		3	2					3
CO3		3						
CO4		2				2	3	3
CO5					3			
CO6					2	2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Simple linear regression model, multiple linear regression model, least squares estimation, Gauss Markov theorem, properties of the estimates, distribution theory, maximum likelihood estimation; Hypothesis testing - likelihood ratio test, F-test; confidence intervals, Bonferroni-t-intervals, max modulus t intervals, Scheffes's method, estimation with linear restrictions, generalised least squares. (20 Hours)

Module 2:

Residual analysis, departures from underlying assumptions, effect of outliers, collinearity, non-constant variance and serial correlation, departures from normality, diagnostics and remedies. (10 Hours)

Module 3:

Polynomial regression in one and several variables, orthogonal polynomials, indicator variables, subset selection of explanatory variables, stepwise regression and Mallows, C_p- statistics, introduction to non-parametric regression. (15 Hours)

Module 4:

Introduction to nonlinear regression, least squares in the nonlinear case and estimation of parameters, models for binary response variables, estimation and diagnosis methods for logistic and Poisson regressions, prediction and residual analysis; Generalized linear models – estimation and diagnostics. (15 Hours)

Text Books:

1. Montgomery, D.C., Peck, E.A. and Vining, G.G. (2001). *Introduction to Regression Analysis*, 3^{rd} Edition. Wiley. Chapter 2, 3.
2. Seber, A. F. and Lee, A.J. (2003). *Linear Regression Analysis*, John Wiley, Relevant sections from chapters 3, 4, 5.

References:

1. Searle, S. R. (1997). *Linear Models*. John Wiley & Sons, New Jersey.
2. Draper, N. R. and Smith, H. (1998). *Applied Regression Analysis*, 3^{rd} Edition. John Wiley & Sons, New Jersey.
3. Fox, J. (1984). *Linear Statistical Models and Related Methods*, John Wiley, Chapter 5.
4. Christensen, R. (2001). *Advanced Linear Modeling*, Chapter 7, Springer, Switzerland.
5. Abraham, B. and Ledolter, J. (2009). *Statistical Methods for Forecasting*. Wiley, New Jersey.

24-810-0904 Design and Analysis of Experiments-II

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Identify one-way and two-way classifications	Understand
2.	Analyze one-way, two-way classifications, experiments with covariance and model adequacy checking procedures	Analyse
3.	Distinguish different types of basic designs of experiments	Understand
4.	Apply methods of analysing different types of basic designs of experiments	Apply
5.	Discuss factorial experiments and incomplete block designs	Understand
6.	Apply methods of analyzing factorial experiments and incomplete block designs	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2					
CO2	3		2	2				
CO3	3		2					
CO4	2		2			2		
CO5	2			3				
CO6				3				

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Randomization, replication and local control, one-way and two-way classifications with equal and unequal number of observations per cell with and without interaction, fixed and random effects models, model adequacy checking, CRD, RBD and Latin Square designs, orthogonal Latin squares, analysis of co-variance for CRD and RBD. (20 Hours)

Module 2:

Incomplete block designs - BIBD, properties, analysis with recovery of inter-block information and intra-block information, Youden square design, lattice designs, PBIBD, construction of PBIBD, analysis of PBIBD. (15 Hours)

Module 3:

2^n factorial experiments, 3^n factorial experiments, total and partial confounding of treatments in designs, fractional factorial designs, nested designs, asymmetrical factorial designs, split plot and strip plot designs. (18 Hours)

Module 4:

Response surface designs - orthogonality, rotatability blocking and analysis, method of steepest accent, models, properties and analysis. (7 Hours)

Text Books:

1. Montgomery, D. C. (2019). *Design and Analysis of Experiments*, 10^{th} Edition. John Wiley & Sons, New Jersey.

References:

1. Hinkelman, K. and Kempthrone, O. (2007). *Design and Analysis of Experiments, Volume-I*, 2^{nd} Edition. Wiley, United Kingdom.

2. Das, M. N. and Giri, N. C. (2017). *Design and Analysis of Experiments*, 3^{rd} Edition. New Age International Publishers, New Delhi.

3. Joshy, D. D. (1987). *Linear Estimation and Design of Experiments*. New Age International, New Delhi.

24-810-0908 MOOC

Credits (H/W for L-T-P): 2-4 (0-2-0)

Semester X

Semester Credit: 22-24 (Major: 20, Online Course: 2-4); Cumulative Credit: 221								
Code	Course	Course Type	Pre-requisites	H/W for L-T-P	Credits	Marks Distribution		
						CE	ES	Total
24-810-1001	Time Series Analysis	STAT Major - DSC	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1002	Project Work	STAT Major - DSC	None	0-12-0	12	50	50[b]	100
24-810-10xx	Elective - VI	STAT Major - DSE	24-810-0503	2-1-2	4	50	50	100
24-810-1007	MOOC (2-4 credits)[c]	STAT Major - DSE	None	0-2-0	2-4	-	100	100
Elective - VI (Choose any one course)								
24-810-1003	Lifetime Data Analysis	STAT Major - DSE	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1004	Spatial Statistics	STAT Major - DSE	24-810-0801/0901	2-1-2	4	50	50	100
24-810-1005	Advanced Bayesian Computing	STAT Major - DSE	None	2-1-2	4	50	50	100
24-810-1006	Statistics for Clinical Research	STAT Major - DSE	None	2-1-2	4	50	50	100

24-810-1001 Time Series Analysis

Credits (H/W for L-T-P): 4 (2-1-2)

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Assess the stationarity of time series and its decomposition	Evaluate
2.	Identify suitable models for the stationary component of the given time series	Analyse
3.	Analyse Spectral density and periodogram	Analyse
4.	Analyse time series in a state space set up	Analyse
5.	Compute Smooth and filter by Kalman algorithm	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2	1			3		1
CO2	3	2				2		1
CO3			2			3		
CO4			1			3		
CO5			2			2		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Characteristics of time series - time series as a discrete parameter stochastic process, autocorrelation function (ACF) and cross-correlations, stationary time series, estimation of autocorrelations; classical regression in time series context, exploratory data analysis, smoothing methods for time series, Wold representation of linear stationary processes. (15 Hours)

Module 2:

Linear time series models - autoregressive (AR), moving average (MA), autoregressive moving average (ARMA) and autoregressive integrated moving average (ARIMA) models, forecasting and estimation of ARMA models, seasonal ARIMA models, residual analysis and diagnostic checking. (20 Hours)

Module 3:

Spectral analysis - time series in frequency domain, spectral density, periodogram and discrete Fourier transforms, estimation of spectral density, multiple series and cross spectra, linear filters. (12 Hours)

Module 4:

State space models - filtering, smoothing and forecasting using state space models, Kalman smoother, maximum likelihood estimation, missing data modifications. (13 Hours)

Text Books:

1. Shumway, R. H. and Stoffer, D. S. (2017). *Time Series Analysis and Its Applications*, 4^{th} Edition. Springer, Switzerland.

2. Box, G. E. P., Jenkins, G. M., Reinsel, G. C. and Ljung G. M. (2015). *Time Series Analysis: Forecasting and Control*, 5^{th} Edition. Wiley, New Jersey.

3. Brockwell, P. J. and Davis R. A. (1991). *Time Series: Theory and Methods*, 2^{nd} Edition. Springer, New York.

References:

1. Chatfield, C. (2003). *The Analysis of Time Series - An Introduction*, 6^{th} Edition. Chapman and Hall, New York.

2. Abraham, B. and Ledolter, J. (2009). *Statistical Methods for Forecasting*. Wiley, New Jersey.

3. Anderson, T. W. (2011). *The Statistical Analysis of Time Series*, 1^{st} Edition. Wiley, India.

4. Fuller, W. A. (1995). *Introduction to Statistical Time Series*, 2^{nd} Edition. Wiley, United Kingdom.

5. Kendall, M. G. (1990). *Time Series*, 3^{rd} Edition. Oxford University Press, Oxford.

6. Tanaka, K. (2017). *Time Series Analysis: Nonstationary and Noninvertible Distribution Theory*, 2^{nd} Edition. Wiley, New Jersey.

24-810-1002 Project Work

Credits (H/W for L-T-P): 12 (0-12-0)

24-810-1007 MOOC

Credits (H/W for L-T-P) : 2-4 (0-2-0)

List of Electives for VII/VIII/IX/X Semesters

24-810-0705 Categorical Data Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Analyse categorical variables and multi-way tables	Analyse
2.	Understand different probability models and GLM and familiarise with the real life applications	Understand
3.	Calculate odds ratios and relative risks and associated inference procedures	Analyse
4.	Evaluate association rules of different orders	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	1		2		1	2	2	
CO2	3	1	2		3			
CO3	2	1						2
CO4		2		2	2	2		3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to categorical data - categorical data, discrete distributions and related inference problems, statistical inference with categorical data, classes of models for discrete data; Analysis of two-way tables - analyzing 2×2 tables, analyzing $I \times J$ tables, test of independence for ordinal variables, graphs for two-way tables. Analysis of multi-way tables - describing multi-way contingency tables, on partial and marginal tables, analysis of K 2×2 tables, types of independence for three-way tables, graphs for multi-way contingency tables. (15 Hours)

Module 2:

Log-linear models - log-linear models for two-way tables, on inference and fit of log-linear models, log-linear models for three-way contingency tables, hierarchical log-linear models for multi-way tables, maximum likelihood estimation for log-linear models, model fit and selection, graphical models, collapsibility in multi-way tables. (15 Hours)

Module 3:

Generalized linear models and extensions - the generalized linear model (GLM), log-linear model - member of the GEM Family, inference for GLMs, software for GLMs, independence for incomplete tables, models for joint and marginal distributions. (15 Hours)

Module 4:

Association models - basic association models for two-way tables, maximum likelihood estimation for association models, association model selection, features of association models, association models of higher order - the RC(M) model, software applications for association models, association models for multi-way tables. (15 Hours)

Text Books:

1. Kateri, M. (2014). *Contingency Table Analysis: Methods and Implementation Using R*, 1^{st} Edition. Springer, New York.

2. Agresti, A. (2013). *Categorical Data Analysis*, 3^{rd} Edition, Wiley, New Jersey.

References:

1. Powers D.A. (1999). *Statistical methods for Categorical data analysis.* . Academic press Inc. New York.

24-810-0706 Population Dynamics

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the fundamental ideas, objectives and applications of population dynamics	Understand
2.	Employ life table functions and estimate the survival probability by method of MLE	Apply
3.	Understand the fundamental ideas about Leslie matrix techniques	Understand
4.	Apply population projection techniques by using a mathematical models	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2		1		2		3	
CO2		2			3		2	
CO3	2	1			3		2	
CO4	1	3	1		2		2	1

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Sources of mortality data, mortality measures, ratios and proportions, crude mortality rates, specific rates, standardization of mortality rates, direct and indirect methods, gradation of mortality data, fitting Gompertz and Makeham curves. (10 Hours)

Module 2:

Life tables, complete life table, relation between life table functions, abridged life table relation between abridged life table functions, construction of life tables, Greville's formula, Reed and Merrell's formula, sampling distribution of life table functions, multivariate pgf, estimation of survival probability by method of MLE. (15 Hours)

Module 3:

Fertility models; Fertility indices - relation between CBR, GFR, TFR, and NRR stochastic models on fertility and human reproductive process; Dandekar's modified binomial and Poisson models, Brass, Singh models for waiting time distributions, Sheps and Perrin model. (15 Hours)

Module 4:

Population growth indices, logistic model, fitting logistic, other growth models, Lotka's stable population, analysis, quasi stable population, effect of declining mortality and fertility on age structure, population projections, component method-Leslie matrix technique, properties of time independent Leslie matrix-models under random environment. (20 Hours)

Text Books:

1. Biswas, S. (1988). *Stochastic Process in Demography and Applications*. John Wiley & Sons, New Jersey.

2. Biswas, S. (2012). *Applied Stochastic Processes: A Biostatistical and Population Oriented Approach*, 2^{nd} Edition. New Central Book Agency (P) Limited, India.

3. Pollard, J. H. (1979). *Mathematical Models for the Growth of Human Populations*. Cambridge University Press, United Kingdom.

References:

1. Keyfitz, N. (1977) *Applied Mathematical Demography*, 2^{nd} Edition. Springer, New York.

2. Ramakumar, R. (2018). *Technical Demography*. New Age International, New Delhi.

3. Srinivasan, K. (1998). *Basic Demographic Techniques and Applications*, 1^{st} Edition. SAGE Publications, India.

24-810-0707 Biostatistics

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Discuss types of biological data and principles of bio statistical design of medical studies	Understand
2.	Explain the concepts of survival time functions of important parametric models and compare two survival distributions using LR test and Cox's F-test	Analyse
3.	Explain censoring and estimation of parameters using censored data	Understand
4.	Describe competing risk theory and estimate the probabilities of death by ML method	Analyse
5.	Discuss the basic biological concepts in genetics and clinical trials	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3					2	2	2
CO2	2	2	3					
CO3	2	1				2	2	1
CO4			1			2	3	2
CO5	3		2			3	2	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Biostatistics - example on statistical problems in biomedical research, types of biological data, principles of biostatistical design of medical studies; functions of survival time, survival distributions and their applications viz. exponential, gamma, Weibull, Rayleigh, lognormal, distribution having bath-tub shape hazard function, parametric methods for comparing two survival distributions (L.R test and Cox's F- test). (15 Hours)

Module 2:

Type I, Type II and progressive or random censoring with biological examples, estimation of mean survival time and variance of the estimator for type I and type II censored data with numerical examples, non-parametric methods for estimating survival function and variance of the estimator viz. acturial and Kaplan Meier methods. (15 Hours)

Module 3:

Categorical data analysis (logistic regression) - competing risk theory, indices for measurement of probability of death under competing risks and their inter-relations; estimation of probabilities of death under competing risks by ML method; Stochastic epidemic models - simple and general epidemic models. (15 Hours)

Module 4:

Basic biological concepts in genetics, Mendel's law, Hardy-Weinberg equilibrium, random mating, natural selection, mutation, genetic drift, detection and estimation of linkage in heredity, planning and design of clinical trials, phase I, II, and III trials, sample size determination in fixed sample designs, planning of sequential, randomized clinical trials, designs for comparative trials, randomization techniques and associated distribution theory and permutation tests (basic ideas only), ethics behind randomized studies involving human subjects, randomized dose-response studies (concept only). (15 Hours)

Text Books:

1. Biswas, S. (2012). *Applied Stochastic Processes: A Biostatistical and Population Oriented Approach*, 2^{nd} Edition. New Central Book Agency (P) Limited, India.

References:

1. Cox, D. R. and Oakes, D. (1984). *Analysis of Survival Data*, 1^{st} Edition. Chapman & Hall, London.

2. Elandt, R. C. and Johnson. (1971). *Probability Models and Statistical Methods in Genetics*. John Wiley & Sons, New York.

24-810-0805 Reliability Modelling and Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand and discover the system reliability using the concept of structure functions	Understand
2.	Identify the various aspects like monotonic failure rates , bath tub and upside down bathtub shaped failure rates and other related measures for various life time	Evaluate
3.	Understand the various concepts and different notions of ageing used in reliability analysis and their inter relations	Understand
4.	Evaluate the concepts like positive dependency and various measures of dependence via - RCSI, LCSD, WPQD and their inter relations	Evaluate
5.	Estimate the reliability function for complete and censored samples through the maximum likelihood estimation and UMVU estimation and Bayesian method	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3				2	3		
CO2	3		2		2	3	2	
CO3			2		1	3	1	
CO4	1		1	2	2	3	1	
CO5	2		2		2	3	1	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic concepts in reliability, series and parallel systems, k out of n systems and its reliability, coherent systems, reliability of coherent systems, cuts and paths, bounds on system reliability. (15 Hours)

Module 2:

Life distributions, reliability function, hazard rate and mean residual life function, one to one correspondence of these functions, study of life time models viz, exponential, Weibull, Lognormal, Pareto, gamma, Makeham, Rayleigh distributions, proportional hazard models and their characteristics. (15 Hours)

Module 3:

Notions of ageing, increasing failure rate (IFR), increasing failure rate average (IFRA), new better than used (NBU), decreasing mean residual life (DMRL) and new better than used in expectation (NBUE), classes and their duals, loss of memory property of the exponential distribution, closures of these classes under formation of coherent systems, convolutions and mixtures. (15 Hours)

Module 4:

Reliability estimation using MLE - exponential, Weibull and gamma distributions based on censored and non-censored samples, Kaplan-Meier estimates of the distribution function, stress-strength reliability and its estimation. (15 Hours)

Text Books:

1. Barlow, R. E. and Proschan, F. (1987). *Mathematical Theory of Reliability*. Society for Industrial & Applied Mathematics, Philadelphia.

2. Sinha, S. K. (1986). *Reliability and Life Testing*. Wiley, New Jersey.

3. Lai, C. D. and Xie, M. (2006). *Stochastic Ageing and Dependence for Reliability*, 1^{st} Edition. Springer, New York.

References:

1. Barlow, R. E. and Proschan, F. (1985). *Statistical Theory of Reliability and Life Testing*. Holt, Rinehart and Winston, New York.

2. Rao, S. S. (1992). *Reliability-Based Design*, McGraw-Hill, New York.

24-810-0806 Introduction to Information Theory

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe measures of additive entropy and its properties	Understand
2.	Illustrate conditional entropy relative entropy and mutual Information	Analyze
3.	Describe Renyi entropy, conditional Renyi entropy	Understand
4.	Discuss non-additive entropy and its properties	Understand
5.	Describe maximum entropy principle	Evaluate
6.	Compute various inequalities in information theory	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2					1	
CO2	3	2					2	
CO3	2	2					2	
CO4	2	2				2		
CO5	2	2			2	2		
CO6		2	2				2	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Measures of additive entropy - statistical preliminaries, the Shannon entropy, Fadeev characterization, Tverberg characterization, Lee Characterization, properties of Shannon entropy, entropy rate, conditional entropy and information, chain rules for entropy, relative entropy and mutual information, Jensen's inequality and its consequences, the log sum inequality and its applications, the Renyi entropy and its characterizations, conditional Renyi entropy. (18 Hours)

Module 2:

Measures of non-additive entropy - polynomial entropy and their characterizations, non-polynomial algebraic entropy and characterizations, transcendental entropy and characterizations, Tsallis entropy - definition and properties. (12 Hours)

Module 3:

Maximum entropy distributions, examples, entropy based parameter estimation, entropy as a criterion for goodness of fit, dependence of entropy on sample size, comparison of other parameter estimation methods with entropy method. (12 Hours)

Module 4:

Inequalities in information theory - basic inequalities of information theory, differential entropy, bounds on entropy and relative entropy, inequalities for types, entropy rates of subsets, entropy and Fisher information, the entropy power inequality and the Brunn Minkowski inequality, inequalities for determinants, inequalities for ratios of determinants. (18 Hours)

Text Books:

1. Behara, M. (1991). *Additive and Non-additive Measures of Entropy*, 2^{nd} Edition. Wiley-Blackwell, New Jersey.

2. Cover, T. M. and Thomas, J. A. (2006). *Elements of Information Theory*, 2^{nd} Edition. Wiley-Interscience, New Jersey.

References:

1. Kapur, J. N. (2006). *Maximum-Entropy Models in Science and Engineering*, New Age International Publishers, India.

2. Gray, R. M. (2011). *Entropy and Information Theory*, 2^{nd} Edition. Springer-Verlag New York Inc., New York.

3. Tsallis, C. (2023) *Introduction to Non-extensive Statistical Mechanics: Approaching a Complex World*, 2^{nd} Edition. Springer Nature Switzerland AG, India.

4. Singh, V. P. (1998). *Entropy-Based Parameter Estimation in Hydrology*. Springer, India.

24-810-0807 Statistical Analysis of Clinical Trials

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the process of clinical trials and its importance	Understand
2.	Analyse various methods for designing clinical trials	Analyse
3.	Analyse the bio-equivalence for more than two drugs	Analyse
4.	Evaluate designs based on clinical end points	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	2	2		1	3		1	
CO2		1	2	2	2		1	2
CO3		1	1		3		3	
CO4		3	2		2			3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to clinical trials - need and ethics of clinical trials, bias and random error in clinical studies, conduct of clinical trials, overview of phase I-IV trials, multi-center trials; Data management - data definitions, case report forms, database design, data collection systems for good clinical practice; bioavailability, pharma cokinetics and pharmacodynamics, two-compartment model. (15 Hours)

Module 2:

Design of clinical trials - parallel vs. cross-over designs, cross-sectional vs. longitudinal designs, objectives and endpoints of clinical trials, design of phase I trials, design of single-stage and multi-stage phase II trials, design and monitoring of phase III trials with sequential stopping, design of bio-equivalence trials; Inference for 2x2 crossover design - classical methods of interval hypothesis testing for bio equivalence, Bayesian methods, non-parametric methods. (20 Hours)

Module 3:

Power and sample size determination, multiplicative (or log-transformed) model, ML method of estimation, assessment of inter and intra subject variabilities, detection of outlying subjects; Optimal crossover designs - Balaams design, two-sequence dual design; optimal four period designs, assessment of bio-equivalence for more than two drugs, Williams design. (15 Hours)

Module 4:

Designs based on clinical endpoints - weighted least squares method, log-linear models, generalized estimating equations; drug interaction study, dose proportionality study, steady state analysis, interim analysis and group sequential tests, alpha spending functions, analysis of categorical data. (10 Hours)

Text Books:

1. Chow, S.C. and Liu, J.P. (2023). *Design and Analysis of Bioavailability and bioequivalence*, 3^{rd} Edition. CRC Press, New York.

2. Chow, S.C. and Liu, J.P. (2014). *Design and Analysis of Clinical Trials: Concepts and Methodologies*, 3^{rd} Edition. Wiley Series in Probability and Statistics.

3. Fleiss, J. L.(1999). *Design and Analysis of Clinical Experiments*, 1^{st} Edition. Wiley-Interscience, United Kingdom.

References:

1. Friedman, L. M., Furberg, C. D., DeMets, D. L., Reboussin, D. M., and Granger, C. B. (2015). *Fundamentals of Clinical Trials*, 5^{th} Edition. Springer, New York.

2. Jennison, C. and Turnbull, B. W. (1999). *Group Sequential Methods with Applications to Clinical Trials*, 1^{st} Edition. Chapman and Hall/CRC Press, India.

3. Marubeni, E. and Valsecchi, M. G. (2004). *Analyzing Survival Data from Clinical Trials and Observational Studies*, 1^{st} Edition. Wiley-Interscience, United States.

24-810-0905 Operations Research - II

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Examine the properties of linear programming problem	Understand
2.	Solve different types of LPP	Analyse
3.	Solve LPP using duality	Apply
4.	Employ transportation and assignment problems	Apply
5.	Solve non-linear programming problems	Apply
6.	Examine deterministic and probabilistic inventory models	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3			2				
CO2	3							
CO3	3			2				
CO4	3							
CO5	2			2				
CO6	2							

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Linear programming - convex sets and associated theorems, graphical method, definition of linear programming problem, properties of a solution to the linear programming problem, generating extreme-point solutions, simplex computational procedure, artificial variables technique - big M method, two phase method, revised simplex method. (20 Hours)

Module 2:

Duality problems of linear programming - unsymmetric primal-dual problems, symmetric primal-dual problems; Degeneracy and anticycling procedures - perturbation techniques; Transportation problems - general transportation problem, finding initial basic feasible solution, test for optimality, degeneracy in transportation problem, unbalanced transportation problem, maximization transportation problem; Assignment problem - mathematical formulation of the problem, the assignment method (Hungarian method). (18 Hours)

Module 3:

Non-linear programming problem (NLPP) - general non-linear programming problem; Constrained optimization with equality constraints - necessary conditions for a generalized NLPP, sufficient conditions for a general NLPP with one constraint, sufficient conditions for a general problem with $m(< n)$ constraints; Constrained optimization with inequality constraints - Kuhn Tucker conditions for general NLPP with $m(< n)$ constraints; quadratic programming problem, convex programming problems. (12 Hours)

Module 4:

Inventory models : Deterministic inventory models - general inventory model, static economic order quantity (EOQ) models - classic EOQ model, EOQ with price breaks, multi-item EOQ with storage limitation; Probabilistic inventory models - continuous review models - probabilitized EOQ model, probabilistic EOQ model, single-period models - no setup model (Newsvendor model), setup model ($s - S$ policy). (10 Hours)

Text Books:

1. Gass, S.I. (2011). *Linear Programming: Methods and Applications*, 5^{th} Edition. Dover Publications Inc., India.

2. Swarup, K., Gupta, P. K., and Mohan, M. (2022). *Operations Research*, 20^{th} Edition. Sultan Chand & Sons, India.

3. Taha H.A. (2019). *Operations Research - An introduction*, 10^{th} Edition. Pearson Education, India.

References:

1. Ravindran, A., Philips, D.T. and Soleberg, J.J. (2007). *Operation Research: Principles and Practice*, 2^{nd} Edition. John Wiley & Sons, India.

2. Paneerselvam, R. (2023). *Operations Research*, 3^{rd} Edition. PHI Learning, New Delhi.

24-810-0906 Reliability Engineering

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Compute reliability and hazard functions in modelling lifetime data and systems	Apply
2.	Calculate stress-strength based reliability	Analyze
3.	Differentiate maintainability and availability	Analyze
4.	Distinguish different types of failure modes	Understand
5.	Employ reliability tests and analysis of reliability plots	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3		2			2		
CO2	3		2			2		
CO3	2		2					
CO4			2					
CO5	2		2			3		

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Definition of reliability, pattern of failures, factor of safety and reliability, reliability and hazard functions, modelling of failure rates, estimation of failure rates from empirical data, parallel and series systems, (k/n) systems, complex systems, reliability enhancement, reliability allocation. (15 Hours)

Module 2:

Strength based reliability and inference theory - general expression for reliability, expression for probability of failure, reliability when strength and load follow normal, log-normal, exponential and extreme value distribution; Structural Reliability - one member-one load case, single member-several load case, reliability analysis of parallel system. (15 Hours)

Module 3:

Maintainability and availability - maintainability, preventive maintenance, imperfect maintenance, repair time distributions; Availability – availability analysis development of the model; systems with a single component, series and parallel systems, system safety analysis, failure models and effects - analysis, event - tree analysis, failure tree analysis, minimal cut-sets. (15 Hours)

Module 4:

Objectives of reliability test, analysis of failure time, accelerated life testing, censoring and acceleration, sequential life testing, statistical inference and parameter estimation, confidence intervals, plotting of reliability data, Bayesian analysis. (15 Hours)

Text Books:

1. Rao, S.S. (1992). *Reliability - Based Design*, McGraw-Hill, New York.

2. Breneman, J. E., Sahay, C., and Lewis, E. E. (2022). *Introduction to Reliability Engineering*, 3^{rd} Edition. John Wiley and Sons, India.

References:

1. Tobis, P.A. and Trindade, D.C. (2012). *Applied Reliability*, 3^{rd} Edition. CRC Press, London.

2. Rausand, M. and Hoyland, A. (2021). *System Reliability Theory – Models, Statistical Methods, and Applications*, 3^{rd} Edition. Wiley-Blackwell, New Jersey.

3. Villemeur, A. (1992). *Reliability, Availability, Maintainability and Safety Assessment* (Volume 2), John Wiley and Sons, New York.

4. Pages, A., Gondran, M., and Griffin, E. (1986). *System Reliability: Evaluation & Prediction in Engineering*, Springer-Verlag, New York.

24-810-0907 Applications of Integral Transforms

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the basic concepts of integral transforms	Understand
2.	Apply Laplace transform, Fourier transform, Hankel transform and Mellin transform	Apply
3.	Evaluate Hilbert transform, Stieltjes transform, Z-transform	Analyse
4.	Apply Hilbert transform, Stieltjes transform, Z-transform	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		3			3	3		
CO2	3			3	3	3		
CO3	3			3	3	3		
CO4	3				3	3	3	

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic concepts of integral transforms; Fourier transforms - introduction, basic properties, applications to solutions of ordinary differential equations (ODE), partial differential equations, applications of Fourier Transforms to solutions of ODEs, PDEs, and integral equations; evaluation of definite integrals, theorems, Watson's Lemma, solutions to ODE, PDE including initial value problems; Laplace transforms - introduction, existence criteria. (17 Hours)

Module 2:

Laplace (IVP) and boundary value problems (BVP) transforms - convolution, differentiation, integration, inverse transform, Tauberian; applications of joint Fourier-Laplace transform, definite integrals, summation; Hankel Transforms - introduction, properties and applications to PDE; Mellin transforms - introduction, properties, applications; Generalized Mellin transforms. (15 Hours)

Module 3:

Hilbert Transforms, Stieltjes Transform, Z - Transforms, Radon transform, fractional calculus and its application. (13 Hours)

Module 4:

Integral transforms in fractional equation; Wavelet transform - discussion on continuous and discrete, Haar, Shannon, and Daubechies wavelets. (15 Hours)

Text Books:

1. Davies, B. (2002). *Integral Transforms and Their Applications*, 3^{rd} Edition. Springer, New York.

References:

1. Debnath, L. and Bhatta, D. (2014). *Integral Transforms and Their Applications*, 3^{rd} Edition. CRC Press, India.

2. Sarthok Sircar, *Integral Transforms and Their Applications*, NPTEL lecture notes.

24-810-1003 Lifetime Data Analysis

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Understand the basic concepts and ideas of survival analysis	Understand
2.	Examine the properties and methods for standard survival time distributions	Analyse
3.	Estimate survival functions using parametric and non-parametric methods	Evaluate
4.	Apply and interpret semi-parametric and parametric regression models for survival data	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2			1	2	2	
CO2	2	2			1	2	2	
CO3	2	1	2		3	2	1	
CO4	1	1	1		3	2	1	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Basic quantities and models - survival function, hazard function, mean residual life function, common Parametric Models for survival Data; Censoring and truncation - right censoring, left or interval censoring, truncation, likelihood construction for censored and truncated data, counting processes. (15 Hours)

Module 2:

Nonparametric estimation of basic quantities for right-censored and left-censored data - estimators of the survival and cumulative hazard functions for right-censored data, pointwise confidence intervals for the survival function (without derivation), estimators of the survival function for left-truncated and right-censored data, estimation of the survival function for left-censored data, estimating the hazard function; Hypothesis Testing - one-sample tests, tests for two or more samples. (15 Hours)

Module 3:

Semi-parametric proportional hazards regression with fixed covariates - coding covariates, partial likelihoods for distinct-event time data, partial likelihoods when ties are present, model building using the proportional hazards model, estimation for the survival function; Regression diagnostics - Cox-Snell residuals for assessing the fit of a Cox Model, graphical checks of the proportional hazards assumption, deviance residuals. (15 Hours)

Module 4:

Inference for parametric regression models - exponential, Weibull and log logistics; Multiple modes of failure – basic characteristics and model specification, likelihood function formulation, nonparametric methods. (15 Hours)

Text Books:

1. Klein, J.P. and Moeschberger, M.L. (2003). *Survival Analysis - Techniques for Censored and Truncated Data*, 2^{nd} Edition. Springer, New York.

2. Lawless, J.F. (2002). *Statistical Models and Methods for Lifetime Data*, 2^{nd} Edition. Wiley-Interscience, United States. Relevant Sections of the Chapter 9.

References:

1. Kalbfleisch, J.D. and Prentice, R.L. (2002). *The Statistical Analysis of Failure Time Data*, 2^{nd} Edition. Wiley-Interscience, United States.

2. Hosmer Jr, D.W. and Lemeshow, S. (2008). *Applied Survival Analysis - Regression Modelling of Time to Event Data*, 2^{nd} Edition. Wiley-Interscience, United States.

3. Nelson, W. (2004). *Applied Life Data Analysis*, 1^{st} Edition. Wiley-Interscience, United Kingdom.

4. Miller, R.G. (1998). *Survival Analysis*, 2^{nd} Edition. Wiley-Interscience, United States.

5. Deshpande, J. V. and Purohit, S. G. (2016). *Lifetime Data: Statistical Models and Methods*, 2^{nd} Edition. World Scientific, Singapore.

24-810-1004 Spatial Statistics

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe different types of spatial data (geostatistical, areal, point process)	Understand
2.	Understand how spatial autocorrelation plays a role in statistical modeling	Understand
3.	Model geo-statistical data from real life situations	Analyse
4.	Analyse aerial unit data from real life situations	Analyse
5.	Model process data from real life situations	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		3	3	1	2	3	2	
CO2		3	3	1	3	3	1	
CO3	1	3	3	2	2	2	3	3
CO4	1	3	3	2	2	2	3	3
CO5	1	3	3	2	2	2	3	3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction, spatial stochastic process; Types of spatial data - geostatistical process, areal process, point process; Geo-statistical theory - mean, variance and covariance; autocorrelation function, stationarity, variograms. (10 Hours)

Module 2:

Geo-statistical modelling - Gaussian process, spatial autocorrelation, parameter estimation, maximum likelihood method, least square method, model adequacy, spatial residuals, spatial prediction. (20 Hours)

Module 3:

Areal unit modelling - estimation of spatial autocorrelation, conditional autoregressive (CAR) models, parameter estimation, Bayesian estimation. (15 Hours)

Module 4:

Point process data modelling - point process theory, Poisson process, model for complete spatial randomness, test for spatial randomness, parameter estimation; log-Gaussian Cox process. (15 Hours)

Text Books:

1. Lieshout van, M. N. M. (2019). *Theory of Spatial Statistics A Concise Introduction*, 1^{st} Edition. CRC Press, India.

2. Gelfand, A.E., Diggle, P., Guttorp, P. and Fuentes, M. (2010). *Handbook of Spatial Statistics*, 1^{st} Edition. CRC Press, United States.

3. Banerjee, S., Carlin, B.P. and Gelfand, A.E. (2014). *Hierarchical Modeling and Analysis for Spatial Data*, 2^{nd} Edition. CRC Press, India.

References:

1. Peter, J. D. (2023). *Statistical Analysis of Spatial and Spatio-Temporal Point Patterns*, 3^{rd} Edition. CRC Press, London.

2. Gaetan, C. and Guyon, X. (2009). *Spatial Statistics and Modeling*. Springer, New York.

3. Cressie, N. A. C. (2015). *Statistics for Spatial Data*, 2^{nd} Edition. John Wiley & Sons, United States.

4. Waller, L.A. and Gotway, C.A. (2004). *Applied Spatial Statistics for Public Health Data*, 2^{nd} Edition. John Wiley & Sons, United States.

5. Schabenberger, O. and Gotway, C. A. (2023). *Statistical Methods for Spatial Data Analysis*, 1^{st} Edition. CRC Press, London.

24-810-1005 Advanced Bayesian Computing

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Describe various aspects of decision theory	Understand
2.	Construction of utility function in real life situations	Apply
3.	Differentiate the relevance of various loss functions	Analyse
4.	Evaluate the Bayesian estimators arena of statistical methodology	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	3	2				3		
CO2	2	2	1			2		2
CO3		1	2			3		2
CO4		2		3	2			3

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Statistical decision problem – decision rule and loss, randomized decision rule, decision principle, sufficient statistic and convexity, utility and loss functions, standard loss functions, vector valued loss functions. (14 Hours)

Module 2:

Prior information - subjective determination of prior density, non-informative priors, maximum entropy priors, location and scale invariant priors, Jeffrey's prior, ML-II approach to prior selection, conjugate priors, game theory, minimax theorem (without proof), statistical games, method of finding minimax estimators. (16 Hours)

Module 3:

Bayesian hypothesis testing, prior and posterior odds, Bayes factor, Lindley's procedure for test of significance, decision theoretic approach to testing problem, predictive inference-introduction, standard predictive distribution, Laplace rule of succession, prediction for exponential family of distribution, Bayes prediction with induced loss. (15 Hours)

Module 4:

Bayesian inference for the linear model, homoscedastic disturbances, heteroscedastic disturbances, predictive distribution, estimation, hypothesis testing, general linear model, empirical Bayes model, robustness. (15 Hours)

Text Books:

1. Berger, O. J. (1985). *Statistical Decision Theory and Bayesian Analysis*, 2^{nd} Edition. Springer Science & Business Media, New York.

References:

1. Ferguson, T. S. (1967). *Mathematical Statistics-A Decision Theoretic Approach*, 1^{st} Edition. Academic Press, New York.

2. Lehmann, E. L. and Casella, G. (1998). *Theory of Point Estimation*, 2^{nd} Edition. Springer, New York.

3. Parmigiani, G., Inoue, L. Y. T. and Lopes, H. F. (2009). *Decision Theory-Principles and Approaches*, 1^{st} Edition. John Wiley & Sons, United Kingdom.

24-810-1006 Statistics for Clinical Research

Credits (H/W for L-T-P): 4 (2-1-2)
After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1.	Drug discovery and development	Understand
2.	SAS programming	Analyse
3.	CDISC SDTM implementation	Apply
4.	TLF report generation	Apply
5.	Advanced biostatistics using SAS	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1		2		2				
CO2		2						3
CO3		2					2	
CO4		2						

1-Slightly/Low, 2-Moderate/Medium, 3-Substantial/High

Module 1:

Introduction to clinical research, clinical research process, clinical data flow from start to end, types of studies and study designs, introduction to SAS, introduction to PDV, dataset processing and programming, SAS statements, combining datasets - set and merge, SAS functions, good programming practices (GPP), data manipulations, SAS procedures. (20 Hours)

Module 2:

SDTM package introduction and fundamentals, special purpose domains, general observation classes, trial design and relationship datasets, specification development. (15 Hours)

Module 3:

Dataset - ADSL, ADaM basic data structure - BDS, ADaM occurrence data structure – OCCDS, other types of ADaM data structures. (15 Hours)

Module 4:

Reporting procedure, shell overview, Tables, Listings, and Figures, sensitivity analysis and tipping point analysis, missing data, subgroups and covariate analysis, case study on CSR. (10 Hours)

References:

1. https://learn.sas.com/search/index.php?q=clinical
2. https://support.sas.com/en/documentation.html
3. https://www.cdisc.org/standards/foundational/sdtm
4. https://www.cdisc.org/standards/foundational/sdtmig/sdtmig-v3-2
5. https://www.cdisc.org/standards/foundational/adam
6. https://www.cdisc.org/standards/foundational/adam/adamig-v1-1