Syllabus

for

Five Year Integrated Master of Science Programme

(Biological Science, Chemistry, Mathematics, Physics, Statistics)

Centre for Integrated Studies
Cochin University of Science and Technology

Appendix I

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Center for Integrated Studies

5 -Year Integrated M. Sc. (Chemistry/ Mathematics/ Physics/ Statistics)

Regulation, 2020

Preamble: This Regulation shall be called 'Regulation for 5-Year Integrated M. Sc (Chemistry/ Mathematics/ Physics/ Statistics), 2020'. This shall supersede all previous Regulations.

1. Introduction

In the process of the fulfillment of the set objects of the Cochin University of Science and Technology, a Centre for Integrated Studies (CIS) was established in the year 2018-19 to offer 5 year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) for imparting specialized education to the students on completion of their +2 level of education.

2. Courses offered by the Centre

The CIS offers 5-year integrated M. Sc (Chemistry, Mathematics, Physics and Statistics) subjects. The nomenclature of the course shall be 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics).

3. Overview of the Course

The 5-Year Integrated M.Sc (Chemistry/ Mathematics/ Physics/ Statistics) of the Cochin University of Science and Technology is a non-professional course. It is not merely an integrated program that combines pre-graduate and post-graduate studies, but is also trans-disciplinary, cutting across several disciplines. The curriculum is common to all the disciplines for the first four semesters. Students with biology background at the +2 stage and who had left mathematics after the 10th class are expected to put in the required efforts to learn mathematics. Similarly, students who left biology at the +2 stage are expected to learn biology with extra effort. Students of Science subjects require significant amount of Mathematics and Computation throughout the 5-Year program. The University offers bridge courses in the first semester to facilitate this process. The students spend first two years of their programs at the CIS. The students are transferred to their parent Departments at the end of the fourth semester.

4. Admission

The present intake for the 5-Year Integrated M. Sc (Chemistry/ Mathematics/ Physics/ Statistics) is 60 (15 x 4). At the end of 2 nd year, the students will move to their respective Departments based on the choice of their subject of preference and SGPA obtained during the 4 Semesters.15 +/- 3 numbers of students will move to each Department. At the end of the 3 rd Year, the students will be integrated with the M. Sc. courses conducted by the Departments of Mathematics (15), Statistics (15), Chemistry (15) and Physics (15). There can be a variation of +/- 3 from the number 15. Reservation norms will be followed while allotting the students to the different disciplines

4.1. Eligibility and Entrance Examination

1. Admission will be given to students possessing KVPY Scholarship. They need not have to appear for the entrance Test. But they also have to submit the requisite Application and should pay the application fee.
2. All other eligible applicants will be called for the written test to be held at various Centers.
3. Candidates with a minimum of 75% marks at +2 level of education (Intermediate, CBSE/ICSE/HSC/ and all State Boards or Equivalent with science subjects [Biology, Chemistry, Mathematics, Physics]) are eligible to apply. The program is open to all students who have completed/ expect to complete +2 stage with at least three of the four subjects (Physics, Chemistry, Mathematics and Biology) as their optional subjects with a minimum of 75% at +2 level. The 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) is designed to be suitable for students who have an inclination and aptitude to study Science and have plans to build a career by studying Science.

The admission to 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) will be through a common entrance examination. The entrance examination consists of a written test for 450 marks. The written test paper contains 50 objective questions each in Mathematics, Physics, Chemistry and Biology at +2 level. Written test for this program is of three hours duration. It will consist of multiple choice (of four options) questions to be answered as Computer based Online Test. The level of questions shall be consistent with +2 level of education. There is negative marking: each right answer will be given 3 marks; and each wrong answer will be given -1 mark. The question paper shall have four sections. A (Chemistry), B (Mathematics), C (Physics) D (Biology). The students can write questions from any three of the four sections. Specific instructions will be given in question papers.

***Special note*:** At present, the admission is through CAT conducted by CUSAT. Presently, the entrance test is common for 5-Year Integrated M.Sc (Chemistry/ Mathematics/ Physics/ Statistics), 5-Year Integrated M. Sc. in Photonics and the B. Tech. Degree programs. Thus, the question paper pattern is different. There are 125 questions in Mathematics, 75 questions in Physics and 50 questions in Chemistry, all questions carry 3 marks. Even though students applying for 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) are writing the same entrance examination along with 5- Year Integrated M. Sc. in Photonics and the B. Tech. Degree programs, there will be a separate selection list for admission to the 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics). Marks obtained for Mathematics and Physics out of 375 and 225 respectively will be re-calculated to be out of 150 each. Thus, the total marks will be 450.

4.2. Selection List

Students possessing KVPY Scholarship will be admitted directly if 4.1.3 holds. The admission will be through common counselling process. Initially, there will not be any classification of students between the four subjects. After 2 years, the students have to give option for selecting their subject of choice. Allotment to their choice will be depending on their performance (SGPA) in the four semesters. But attempts will be made to keep a balance in the number of students admitted to the 3rd year of the program among the various Departments, by allowing a variation of +/- 3 from the normal value of 15. Reservation norms will be followed while allotting the students to the different disciplines.

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:

(a) First criterion: Total marks obtained by the candidates for Chemistry and Physics taken together in the entrance examination.

(b) Second criterion: Marks obtained for Chemistry. If the tie has not been broken still, the marks obtained for Physics will be counted.

(c) If the tie has not been broken still, the normal procedure of the University will be followed.

5. Reservation

All relevant reservation rules (Kerala State) will be followed for the initial admission to the course as well for the allotment of the students to the four branches of study after the 2nd Year. Similarly, concession in fees for the course also will be based the Government of Kerala Rules. The seat matrix based on reservation similar to other non-professional courses in the University is applicable.

5. 5- Year Integrated M. Sc. (Chemistry/ Mathematics/ Physics/ Statistics)

The subjects for the 5-Year Integrated M. Sc. (Chemistry/ Mathematics/ Physics/ Statistics) are common in the first 4 semesters. The students with Biology background at +2 stage, who left Mathematics after 10th are expected to put in necessary effort to learn Mathematics needed for other courses. Similarly, the students who studied Mathematics at +2 stage and left Biology after 10th are expected to learn necessary biology. To provide necessary help in this direction, the University runs bridge courses in the first semester. The students who join the program are required to attend the relevant bridge courses. They are also encouraged to approach and seek help of the faculty members concerned and their Mentors.

6. **Extra Course/Credits** A student can take courses over and above those stipulated for a semester and can accumulate extra credits in a given semester. During the first two Semesters, Courses on English and French/ German/ Hindi/ Malayalam will be offered. These courses cannot be taken in lieu of the regular subject credit course/s.

8. Audit Course

There is a provision for auditing of 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 the CIS in writing. Courses thus audited should also be indicated in the Registration forms along with other courses opted for that semester. Only one Audit Course is allowed per semester.

9. Possibility of Tutorial

On the basis of the request of a sizeable number of students for additional guidance in coping up with the subjects; the Heads/ Directors of the participating Departments/Schools will be requested to provide tutorial support for small groups subject to availability of human resources.

10. Enrichment Program

CUSAT Carrier Guidance Bureau organizes Spoken English / UGC NET Classes / CSIR-UGC/JRF/NET Classes (Paper-1) for the benefit of students. The students are encouraged to undertake internships/ summer research programs during the winter and summer breaks.

11. Attendance

A student needs to attend at least 75% of the classes held in each course in order to be eligible to write the end-semester examination. If the student has been absent for medical reasons, the shortfall of attendance would be condoned up to 5% subject to submission of the relevant medical certificate to the Coordinator, CIS. If, due to unusual circumstances, the student's attendance falls far short of the required percentage, he/she may bring it to the notice of his/her course instructor/ teacher/Coordinator/Assistant Coordinator well in advance. He/she can then explore the possibility of dropping the semester and opt for registration during the next semester as per University rules. Students, who are not found eligible to take semester examinations due to shortfall of attendance, may make up the loss by appearing in the Summer Semester (Offered during May-June) of every year. He/ she may also be considered for re-admission to the course concerned when it is offered in the following academic year. It may be noted that it is the responsibility of student to monitor his/her attendance and inform the instructor about his/her absence. 75% attendance is the norm for writing end-semester examinations.

12. Internal Assessment

CUSAT has a scheme of rigorous and continuous internal assessment. The student can get the best out of this system if he/she is well informed about how it works right from the beginning. Schedule and nature of tests/assignments/quizzes that are due may be followed. The specific nature of the assignments/tests is discussed by the faculty in the class and can vary from course to course. In case of any doubt, the student may get in touch with the faculty concerned. The student will be given a minimum of three assessments (internal examinations) per semester in each course from which the best two grades/marks will be considered for the purpose of calculating the result of continuous internal assessment. This will make part of one's final grade in the course. The Laboratory Courses will have only Continuous Assessment.

13. End-semester Examination

A final examination at the end of the semester in each course will follow the internal assessments during the semester. The end semester examination is conducted in a totally internal manner. The setting of question papers and evaluation are done by the concerned course teacher. The final result in each course is calculated on the basis of continuous assessment and performance in the end-semester examination.

13.1 Scheme of Examination

The performance of each student enrolled in a course will be assessed at the end of each semester. Evaluation of 5 - Year Integrated M. Sc (Chemistry/ Mathematics/ Physics/ Statistics) is done under the Grading System. There will be 6 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. 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. For Laboratory Courses (Practical Courses) and Open Ended Laboratory Courses, there will be only Continuous Assessment. For the Open Ended Laboratory Courses, at the end of each 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.

13. 2 Computation of SGPA / CGPA

Evaluation of 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) is done under the Grading System. There will be 6 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. 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 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., SGPA (Si) = $\sum(C_i \times G_i) / \sum C_i$ Where Ci is the number of credits of the i th course and Gi 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. CGPA = $\sum(C_i \times S_i) / \sum C_i$ Where Si is the SGPA of the i th semester and Ci is the total number of credits in that semester. In order for a student to get a pass in a course in the End-Semester Examination, he/she has to score at least 45% marks in the End –Semester Examination and also a total of 50 % marks including the marks for the continuous assessment and end-semester examination. The students who pass all the courses and secure SGPA 6.0 (D Grade) or above in a semester will be given Semester Grade Transcript indicating the marks secured, grades for all the courses and SGPA. The nomenclature for the course shall be 5-Year Integrated M. Sc. (Chemistry/ Mathematics/ Physics/ Statistics).

13.3 Supplementary Examinations

Students should obtain a minimum of ‘D’ grade in each course in order to get a pass in the 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics). Students who obtain less than ‘D’ Grade in any course, may be permitted to take the supplementary examination in the course/s concerned within a week after the commencement of teaching of the next semester or in accordance with the schedule notified. The higher marks obtained in the Regular Examination or the Supplementary Examination will be counted for assessing the Grade. Those students who get less than ‘D’ grade in the supplementary examination also, shall have to reappear for the End Semester

Examination during the succeeding year with the approval of the Head/Director of the Department/School concerned and the Coordinator of the CIS. Such approval should be obtained at the beginning of the semester concerned. Those students who are not satisfied with the grades obtained (C or D), in a course in a semester can opt for improving the grade by appearing in the exam during the supplementary exams conducted after each semester. Such students can opt for improvement for only one course after the first semester, two courses after the second semester (if the facility was not exercised after the first semester), three courses after the third semester (if the facility was not exercised after the first and second semesters) and so on. Better of the two cases will be counted for calculating the Grades.

13.4. Special Supplementary Examinations

The 5-year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) students, who after completion of the prescribed duration of the course, are left with backlogs, are eligible to appear for special supplementary exams. The students shall have to clear all the backlogs and should get a pass before the expiry of Two Years after the completion of the regular course.

13.5. Improvement Examinations

Students securing 'C or D' grade in the course of a semester may be allowed to improve their marks through the Improvement Examinations. Appearance at such an examination in the course will be allowed as per Clause 13.3 above. The improvement examinations will be conducted along with the supplementary examinations within a week of the commencement of the teaching of the next semester or as per the schedule prescribed. For the purpose of determining the Grades, the better of the two performances in the examinations will be taken into consideration.

13.6. Summer Semester

Those students who have failed in certain courses, or who were unable to write the end semester exams or who did not have sufficient attendance for writing the exams can register themselves for the summer semester offered during May-June and make up their losses. 13.7. Readmission Students who are not found eligible to take semester examinations and also those who are not promoted to the next semester of the course may be considered for readmission to the semester concerned of the immediately following academic year. Such students should seek readmission before the commencement of classes for the semester concerned or within a week of the commencement of the semester concerned, if they are appearing in the supplementary examinations. Such students are given an option either to undergo instruction for all the courses of the semester concerned or instruction in only such courses in which they have failed on the condition that the option once exercised will be binding on the student concerned.

13.7. Readmission

Students who are not found eligible to take semester examinations and also those who are not promoted to the next semester of the course may be considered for readmission to the semester concerned of the immediately following academic year. Such students should seek readmission before the commencement of classes for the semester concerned or within a week of the commencement of the semester concerned, if they are appearing in the supplementary examinations. Such students are given an option either to undergo instruction for all the courses of the semester concerned or instruction in only such courses in which they have failed on the condition that the option once exercised will be binding on the student concerned.

13.8. Backlogs

No student of the 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) shall be allowed to move to the next semester, if he/she has a backlog of more than 2/3 of the courses of that semester subject to a maximum of 6 backlogs at any given point of time including the backlogs of previous semester/s, if any.

13.9. Re-evaluation

After the evaluation of the answer scripts of the End Semester Examination, the Students shall be allowed to check their answer scripts. If the students have any complaint regarding the award of marks, the course teacher has to verify the complaints and should try to resolve them then and there. The Students can also request for re-evaluation of the answer scripts if they wish so. Request from the students for re-evaluation should reach the Head of the Department/ Coordinator, CIS within 5 days of the announcement of the results. On the basis of representation submitted by students every School/Department/Centre will constitute a Grievance Committee consisting of 3 or 4 teachers to examine the complaints received from the students regarding their assessment.

14 Exit Option

The 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) is a full time regular course. Option of Exit with a Bachelor’s degree shall be introduced for desiring students. The distinguishing features of the exit option are:

I. It will be available at the end of three years in the case of the 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) students. Exit with a Bachelor’s degree is subject to fulfillment of the requirements of the First Degree Programs consistent with other Universities in the State.

II. Students who seek to opt out after 3 years (six semesters) should have passed all the courses of the preceding six semesters. The option will not be available to students who have backlogs. For exercising the Exit Option, the students should have secured 136 Credits during the 6 Semesters.

III. Students who exercise 'Exit option' at the end of three years of 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) will be given B.Sc. Degree Certificates. The students will be given B. Sc. Degree in Chemistry or B. Sc. Degree in Mathematics or B. Sc. Degree in Physics, on the basis of the subject of choice. The students, who have opted for studying Statistics after the 4th Semester, will be conferred with B.Sc. degree in Mathematics, if they avail the exit option.

IV. Students who do not exercise 'Exit option' will be given 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) at the end of five years.

V. The Students who exercise the Exit Option have to surrender the Mark lists of the previous semesters. They will be issued new mark lists in conformity with the B. Sc. Degree that will be conferred to them.

15 Merger with the Regular M. Sc.

In the Fourth Year, students of the 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) will be integrated with the students admitted for the regular M. Sc. courses conducted by the Departments. However, the students will continue to be attached with the CIS for all the administrative matters

16 Research orientation

There will be a component of research project in the last year (5th year) of the 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) and students are also encouraged to take up internships in the winter and summer breaks. During the first three years, as far as possible, students may undertake at least one Summer Research Project outside the University. There will be provisions for open ended labs or minor projects in the V and VI Semesters.

17 Students' Welfare

The office of the Director of Students' Welfare will look after the welfare of the students with active support from the elected representatives of the students, Faculty and administration. A Student Counseling Service by professionals is available in the University. In the case of any student requiring parental guidance, his/her parents will be informed accordingly. There is a Students' Union which caters to the students' interests and promotes cultural and sports activities.

18 Gender Justice Committee

CUSAT is committed to providing a place of work and study, free of sexual harassment, intimidation or exploitation. The Committee Against Sexual Harassment (CASH) at CUSAT is the University's instrument for addressing issues/grievances/cases of sexual harassment and recommending their redressal. The Constitution of India entitles every individual the right to live with human dignity, free from exploitation. It is in this spirit that CUSAT expects that its entire community, including students, faculty, staff and officers – will treat each other and visitors to the University with respect. Anyone violating this principle is subject to disciplinary action.

19 CIS Grievance Committee

To attend to the student's general grievances, to conduct general counseling from time to time and to counsel the students individually on various issues and whenever the need arises, CIS Grievance Committee will be constituted. This Committee will look into the grievances of CIS students.

Post Script: *The new regulations (Regulations 2020) shall be made applicable to the students of the current batches (2018 and 2019 admissions) also, particularly with regard to the Exit Option.*

Coordinator, Centre for Integrated Studies

Syllabus

for

Five Year Integrated Master of Science Programme

(Biological Science, Chemistry, Mathematics, Physics, Statistics)

Centre for Integrated Studies
Cochin University of Science and Technology

SYLLABUS FOR SEMESTER I,II,III,IV

Programme Objective

The five-year Integrated Post-Graduate course in Chemistry aims to impart a sound foundation in basic sciences with a focus on transdisciplinary subjects in order to build human resources for innovative research in Chemical Science and train competent manpower who can take challenges in teaching and research.

Programme Outcomes

On successful completion of the five-year Integrated M. Sc. Chemistry programme, studentswill be able to

P.O.1: acquire systematic and coherent understanding of the fundamental concepts.

P.O.2: demonstrate comprehensive knowledge and understanding of both theoretical and experimental/applied chemistry in various fields.

P.O.3: design and perform the chemical synthesis and characterize the products.

P.O.4: design and execute experimental routines for detection and quantification of chemicalentities.

P.O.5: analyze the kinetics and energetics of chemical processes and infer the mechanism.

P.O.6: demonstrate the basic principles of instrumental methods of analysis.

P.O.7: operate advanced instruments and related soft-wares to execute in-depth analysis ofchemical problems.

P.O.8: design and develop new molecules/processes with industrial and societal applications.

P.O.9: acquire skills for future employment in academia and industry.

P.O.10: demonstrate knowledge relevant to the regional, national and international development needs.

SEMESTER: 1

Semester Credit: 23 (Core: 23; Elective: 0) Cumulative Credit: 23

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
ENG 10101	English – I	Core	2	2-1-0	50	50	100
	Language						
MAL 10101 HIN 10101 FLG 10101	Malayalam - I Hindi – 1 German – 1	Core	2	2-1-0	50	50	100
CHE 10101	Atomic Structure andChemical Bonding	Core	3	3-1-0	50	50	100
PHY 10101	Mechanics	Core	3	3-1-0	50	50	100
BIO 10101	General Biology	Core	3	3-1-0	50	50	100
MAM 10101	Calculus-I	Core	4	4-1-0	50	50	100
CHE 10102	Quantitative Analysis Lab	Core	2	0-0-6	100	-	100
PHY 10102	Physics Lab (Mechanics)	Core	2	0-0-6	100	-	100

BIO 10102	General Biology Lab	Core	2	0-0-6	100	-	100

SEMESTER: 2							
Semester Credit: 23 (Core: 23; Elective: 0) Cumulative Credit: 46							
Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
ENG10201	English – II	Core	2	2-1-0	50	50	100
MAL10201 HIN10201 FLG10201	**Language** Malayalam – II Hindi – II German – II	Core	2	2-1-0	50	50	100
CHE10201	Periodicity, Nuclear Chemistry, Metallurgy and Acid Base Chemistry	Core	3	3-1-0	50	50	100
PHY 10201	Waves and Optics	Core	3	3-1-0	50	50	100
BIO 10201	Biochemistry	Core	3	3-1-0	50	50	100
MAM 10201	Linear Algebra, Group Theory	Core	4	4-1-0	50	50	100
CHE10202	Inorganic Qualitative Analysis Lab	Core	2	0-0-6	100	-	100
PHY 10202	Physics Lab (Waves and Optics)	Core	2	0-0-6	100	-	100
BIO 10202	Biochemistry Lab	Core	2	0-0-6	100	-	100

SEMESTER: 3

Semester Credit: 25 (Core: 25; Elective: 0) Cumulative Credit: 71

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10301	Introductory Organic Chemistry	Core	3	3-1-0	50	50	100
PHY 10301	Electricity and Magnetism-I	Core	3	3-1-0	50	50	100
BIO 10301	Cell Biology	Core	3	3-1-0	50	50	100
MAM 10301	Calculus-II	Core	4	4-1-0	50	50	100
MAM 10302	Mathematical Methods-I	Core	4	4-1-0	50	50	100
EVS10301	Environmental Science	Core	2	2-1-0	50	50	100
CHE10302	Organic Qualitative Analysis Lab	Core	2	0-0-6	100	-	100
PHY 10302	Physics Lab (Electricity andMagnetism)	Core	2	0-0-6	100	-	100
BIO 10302	Cell Biology Lab	Core	2	0-0-6	100	-	100

SEMESTER: 4

Semester Credit: 25 (Core: 25; Elective: 0) Cumulative Credit: 96

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10401	Introductory Physical Chemistry	Core	3	3-1-0	50	50	100
PHY 10401	Quantum Physics and Relativity	Core	3	3-1-0	50	50	100
BIO 10401	Molecular Biology andGenetics	Core	3	3-1-0	50	50	100
MAM 10401	Mathematical Methods-II	Core	4	4-1-0	50	50	100
STA 10401	Probability and Statistics	Core	4	4-1-0	50	50	100
COM10401	Basic Computer Science	Core	2	2-1-0	50	50	100
CHE10402	Physical Chemistry Lab	Core	2	0-0-6	100	-	100
PHY 10402	Physics Lab (Modern Physics)	Core	2	0-0-6	100	-	100
BIO 10402	Molecular Biology andGenetics Lab	Core	2	0-0-6	100	-	100

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Syllabus for English for the first & second semesters of IMSc

Name of subject: English -ENG 10101

Semester I

Instructional Objectives

I. Poem (Semester I)

1. To enable the students to enjoy the beauty of the lives & lines of the poets.
2. To develop the students' power of imagination.
3. To give refinement of thoughts.
4. To develop sensibility.
5. To develop a spontaneous overflow of powerful emotions.
6. To train the students to express their thoughts in a soft manner.
7. To tune the ears of the students towards musical recitation.

II. Drama (Comedy for Sem I and Tragedy for Sem II)

1. To acquire communicative skills, language skills, expression of proper emotion in the proper way at the proper time.
2. To procure ability for situational analysis by acting out a play.
3. Role play- Script Writing – Improvisation can be developed.
4. The histrionic talent in the students can be brought out.

III. Prose /Stories (Semester II)

1. To train the students to read aloud with correct pronounciation, stress and intonation.
2. To familiarise the students with ideas of great writers.
3. To enjoy the art of story telling /story writing.
4. To master the art of reading which is a complex skill involving a number of psycho - physical operations.
5. To understand the English language without undue emphasis on its metrical structure.
6. To learn sequence and evolution of ideas and paragraphing.
7. To know the difference between the formats of fiction and non fiction.

IV. Grammar (Semester I and Semester II)

1. To get knowledge of linguistic competence.
2. To use grammar as a tool/resource in the comprehension and creation of oral/ written discourse efficiently, effectively and appropriately according to the situation.
3. To speak and write mistake - free English.

V. Composition (Semester I and Semester II)

1. To improve diction and applied grammar
2. To familiarise the writing of introduction, body and conclusion.
3. To exercise free thinking & confident expression.

Detailed Syllabus
Semester I

Sl. No.	Poem	Author	Taken From	Publisher	Key points
1.	My Heart Leaps	William Words Worth	Favourite Poems Paper Back	DoverThrift Edn. 1992	"The child is the father of the man." The importance of childhood wonder and its pure delight.
2.	Lochinvar	Sir Walter Scott	Lochinvar and Other Poems	Shamrock Eden Publishing. 2010	Perseverence and determination. The power of true love
3.	My Grand Mother's House	Kamala Das	Selected Poems Devindra Kohli (Ed.)	India Penguin Modern Classics 2014	Quest for love and Kamala's personal experiences. Nostalgia for ancestral home.
4.	Invictus	William Ernest Henley	Selected Poems & Prose of W E Henley by John Howlett (Ed.)	Sussex Academic Press 2017	Forgiveness embodied mostly by Nelson Mandela. Healing of mental wounds.
5.	The Truth About the Floods	Nizzim Ezekiel	Collected Poems Introduction by John Thieme	Oxford University Press 5th Edn 2005	People suffer no matter what the govt claims. As the nation reels from the worst floods in decades, it appears that the public is kept in the dark.

Prose:

I have a Dream Speech by Martin Luther King
(Writings and Speeches that Changed The World – Harper Collins 1992)

Drama:

The Proposal — Author: Anton Chekov
(Harper Perennial 1998 – Plays of Anton Chekov)

Specific Outcome for Poetry

1. A musical sense is created.
2. Imagination, creativity and awareness of sonority and rhythm are developed.
3. The cosmic music of poetry is heard by the inner ear and enjoyed by the inner senses.
4. The timbre and tone of voice become finetuned when poetry is heard or recited with cadences & ups and downs of stress and intonation.

5. Poetry learning – sows the seeds of goodness and nobility in the soul. While poetry goes to the heart, Prose goes to the brain.

Grammar & Composition

Grammar:

1. The letter, syllable,word,phrase,sentence,clause.
2. Main parts of speech -8nos. with elaborate study and application of each.
3. Types of sentences.
4. Pronouns
   Personal & Possessive pronouns
   Number - Cardinal/ordinal
5. Gender
6. Case
7. Types of adjectives:
   Degrees of comparison
   Quantitative & Qualitative
8. Adverb:
   Types of adverbs
   Comparison of adverbs
9. Preposition
   Prepositional endings, phrases
10. Conjunction
    Co-ordinating conjunctions
11. Punctuation
12. Question tags – Positive & Negative
13. **The verb**
    Agreement of subject and verb
    The infinitive, the gerund , the past participle
    Transitive & Intransitive
    Auxilliary
    Conditional
    Imperative
    Irregular verbs
    Parsing of sentences
14. Basic Phonetics
15. Basic articulation

Composition:

1. Comprehension passage—rules and format
   Exercises-5 passages
2. Precis writing—rules and format

Exercises-3 precis

3. Expansion of proverb-3 nos.
4. Condensation and Paragraph writing-3 nos
5. Essay
6. Use of mindmapping/track fan.
7. Rules of essay writing
8. Different types of essays like:-

   Descriptive essay
   Expositional essay
   Argumentative essay
   Subjective & objective essay
   Narrative essay etc.

Activities with Creativity:

Storytelling-Oral one sentence each for the whole class
Newspaper reading—oral , with class discussion
Debate & Group discussion-Theory and practice.
Public Speaking, Personality development and confidence building
Movie shows that provide Edu- tainment ,for a class discussion later.
Educational tour to Centres of Art –Culture-Literature & famous Libraries

Prescribed Book

English Grammar & Composition – Wren & Martin

Books for Reference

Plain English at Work – Edward P. Bailey
English Grammar – An outline – Rodney Huddleston
Wordsworth Companion To Literature In English - Ian Ousby

COCHIN UNIVERSITY OF SCIENCE & TECHNOLOGY

Syllabus for English for IMSc

Name of subject:English -ENG 10201

Semester II

Prose:

Sl. No.	Story	Author	Taken From	Publisher	Key points
1.	The Bet	Anton Chekov	The Bet & Other Stories Or Best Short Stories of Anton Chekov	BiblioLife 2009 Jaico Publishing House 1st Edn. 2016	The Story teaches us what is really important in life and shows the shallowness of material wealth. A person internally rich, does not wish for anything.
2.	Temple Thief	Dr. Shashi Tharoor	The Five Dollar Smile: Fourteen Stories	Penguin Books. 2015	Demystification of a myth through parody, irony, foresight, satirical narration and jarring human sensibility. Man is never born a criminal, he is made one. The blending of virtue and vice is like Faction – the blending of fact and fiction.
3.	The Open Window	Saki	The Complete Short Stories of Saki	Random House Reprint Edn. 2016	Neurotic hypochondriacs are boring and deserve no sympathy. With the gift of the gab, an ingenuous story teller can present a tall tale.
4.	Home Coming	Rabindranath Tagore	Best of Rabindranath Tagore	Shrishti Publishers 2012	The sad fate of a 14 year old, Phatik Chakravarty, who was more sinned against than sinning. Nostalgia and home sickness though selfmade, is heart rending to the reader, when ultimately Phatik leaves the world after getting love from his mother for the first and the last time.
5.	On Saying	A.G. Gardiner	Selected Essays	Ingram Short Title 2012	The theme of courtesy and the benefits of being courteous to

	Please				others.
6.	The Gift of the Magi	O'Henry	Gift of the Magi and other Short Stories	Dover Thrift Edn. 1992	Selflessness and true love are the greatest gifts of all.

Specific Outcome for Prose

1. The students will understand the noble yet subtle thoughts of the great minds whose ideas they share.
2. Practical wisdom becomes assertive without sentimental and rash decisions.
3. Gives the student a firm head on a firm pair of shoulders by imbibing the truth and values of life along with the acceptance of the same.
4. Improving their own writing skills in different genres.

Drama:

Monkey's Paw Author: W.W.Jacobs
(Perfection Learning 1979)

Vocabulary, Grammar & Composition:

1. Figures of Speech—with examples from text & class practice
2. Direct & Indirect Speech with proper introductory words such as— He guessed that, she argued that, they exclaimed that,I wondered whether..etc
   50 Exercises:
3. Words that are commonly confused /misinterpreted
4. Synonyms & antonyms
5. Parsing of sentences.
6. Articles-usage & practice
7. Tenses –(contd.)
   Agreement of the verb with the subject—(contd.)
   Active voice & Passive Voice
   Finite & non-finite
   Verbs of concession-may -might, can -could, will- would, shall-should
   Verbs of command, request, advice
8. Modern idioms and accepted slangs & their usages
9. Basic phonetics (contd.)
   Basic articulations(contd.)

Composition:

1. Expansion of outline story with a moral .

2. Story telling (advanced)
3. Writing the first line of a para/story/essay/article, in three different ways
4. Writing the last line of a para/story/essay/article, in three different ways.

Business Communication:

Writing a Circular

Writing a notice

Writing a CV

Preparing a concise as well as a lengthy biodata

Reportage

Debate on current affairs

Group Discussions on local, national & international affairs

Public Speaking-theory & practice (advanced)

Summarising the book taken & read from the library.

Extra curricular activities

Theatre Arts (optional)

Educational tours – Group chat & interview with learned scholars & people of letters in their work place/residence

Literary/language quiz competitions

Quotation competitions(quotes of famous mpeople)

Essay competitions

Elocution & extempore competitions

Skits in English.

To Sum up (The final outcome):

1. Prose harvests the seeds sown by poetry and reaps the effects of practical thinking, realistic decision and their metriculous implementation.
2. The students will understand that Prose is the written or spoken form of language.
3. There is no special formats such as lists or tables.
4. There is no special rythm in prose except in those works from very eloquent and poetic thinkers

and philosophers whose diction will be unconsciously flowery; whereas in poetry there is rhythm, music, soft ideas and etherial sensibility.

At the end of one academic year, each student is sure to assimiliate both. He will come out of his course as a refined individual with a lot of finesse.

Scheme of Course and Examination:

1. Number of Credits 4
2. Number of hours in each semester =64 (16x4=64)
3. Duration - one hour each. Internal assessment – Three tests of 50 marks each. Two better marks out of the three will be taken.

End Semester Examination:

Time : 3 Hours
Max: Marks 50 (Grammar & Composition :15 Marks + Literature: 35 Marks)

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കൊച്ചി ശാസ്ത്ര സാങ്കേതിക സർവകലാശാല

ബിരുദ തല പ്രോഗ്രാമുകൾക്കുള്ള മലയാളം കോഴ്സ്

ഫലം അടിസ്ഥാനമാക്കിയുള്ള പാഠ്യപദ്ധതി

(2020-21 അധ്യയന വർഷം മുതൽ)

<u>സെമസ്റ്റർ -1 കഥയും കവിതയും</u> (ആഴ്ചയിൽ അഞ്ചു മണിക്കൂർ വീതം)

മൊഡ്യൂൾ -1 (36 മണിക്കൂർ)

മലയാളകവിതയുടെ ആധുനിക മുഖവും ആധുനികാനന്തര മുഖവും പരിചയപ്പെടുത്തുന്നു. നവോത്ഥാനം- കവിത്രയം- ഇടപ്പള്ളികവിതകൾ- റിയലിസം- കാല്പനികത ആധുനികാനന്തര പ്രവണതകൾ--സ്ത്രീ,ദളിത് , പരിസ്ഥിതി ദർശനങ്ങൾ - ഭാഷാപരമായ സവിശേഷതകൾ.

പാഠങ്ങൾ

1. നളിനി - കുമാരനാശാൻ

(76 -88 ശ്ലോകങ്ങൾ ; തന്നതില്ല പരനുള്ളുകാട്ടുവാൻ ... മന്ത്രമായതെതിർവാദ്യ ഘോഷിതൾ)

2. പണിമുടക്കം - ഇടശ്ശേരി ഗോവിന്ദൻനായർ
3. [illegible] - കടമ്മനിട്ട രാമകൃഷ്ണൻ
4. കൗസല്യ - വിജയലക്ഷ്മി
5. ഐഡന്റിറ്റി കാർഡ് - എസ് ജോസഫ്

മൊഡ്യൂൾ -2 (36 മണിക്കൂർ)

മലയാളകഥയുടെ ആദ്യകാല സ്വഭാവങ്ങളും പുതുകാല പ്രവണതകളും പരിചയപ്പെടുത്തുന്നു ചെറുകഥ എന്ന വിഭാഗം - തുടക്കകാലത്തെ പ്രവണതകൾ -തകഴി-ദേവ് -ബഷീർ-റിയലിസം-കാല്പനിക പ്രവണതകൾ- ആധുനിക , ആധുനികാനന്തര പ്രവണതകൾ-പാർശ്വവൽക്കരിക്കപ്പെട്ട വിഷയങ്ങൾ പ്രധാന സ്ഥാനത്തേക്ക്-സ്ത്രൈ, ദളിത്, പരിസ്ഥിതി , ഭാഷ- സമകാലിക പ്രവണതകൾ

പാഠങ്ങൾ

1. ജന്മദിനം - വൈക്കം മുഹമ്മദ് ബഷീർ
2. കന്യകയുടെ പുല്ലിംഗം - സാറാ ജോസഫ്
3. ഒരു [illegible] ജീവിതം - സി.അയ്യപ്പൻ
4. രത്നാകരന്റെ ഭാര്യ - ചന്ദ്രമതി
5. മുട്ടയോളം വലിപ്പമുള്ള ധാന്യമണികൾ - ഇ.സന്തോഷ് കുമാർ

<u>സഹായക ഗ്രന്ഥങ്ങൾ</u>

1. ചെറുകഥ : ഇന്നലെ ഇന്ന് - എം. അച്യുതൻ
2. മലയാളകവിതാ സാഹിത്യ ചരിത്രം - എം ലീലാവതി

സെമസ്റ്റർ - II ഗദ്യവും നാടകവും (ആഴ്ചയിൽ രണ്ടു മണിക്കൂർ വീതം)

മൊഡ്യൂൾ -1 (36 മണിക്കൂർ)

മലയാളഗദ്യത്തിന്റെ കരുത്ത് - മലയാളത്തിന്റെ വിചാര രീതി കൾ - നവോത്ഥാന ചിന്തകൾ -മതേതരത്വം - ശാസ്ത്രാവബോധം - മലയാളഭാഷ - സംസ്കാരം- ഗദ്യത്തിന്റെ രീതിയും സൗന്ദര്യവും.

യുക്തിബോധം - കുറ്റിപ്പുഴ കൃഷ്ണപിള്ള

2. കോടതി നടപടികൾ നാട്ടുകാരുടെ ഭാഷയിൽ - എൻ. വി.കൃഷ്ണവാരിയർ
3. അന്നവിചാരം -കുഞ്ഞുണ്ണി
4. മലയാളിയുടെ രാത്രികൾ - കെ.സി.നാരായണൻ
5. വെ[illegible] മുടിനാരുകൾ - കല്പറ്റ നാരായണൻ
6. ചോറിന്റെ മണമുള്ള ചേറ്(ആമുഖം അദ്ധ്യായങ്ങൾ) -പള്ളിക്കൽ [illegible]

മൊഡ്യൂൾ -2 (18 മണിക്കൂർ)

മലയാളത്തിന്റെ ദൃശ്യപാരമ്പര്യം- കഥകളി- കൂത്ത് , കൂടിയാട്ടം നാടകം , സിനിമ - സമൂഹവും ദൃശ്യകലയും -സ്വാധീനങ്ങൾ -പുതുപ്രവണതകൾ.

1. ഓരോരോ കാലത്തിലും (നാടകം) - കെ.വി.ശ്രീജ
2. അകത്തളത്തിലെ സ്ത്രീകൾ (നാടകം) - ഐ.ഷൺമുഖദാസ്

സഹായക ഗ്രന്ഥങ്ങൾ

1. കൈരളിയുടെ കഥ - എൻ.കൃഷ്ണപിള്ള
2. മലയാള നാടക സാഹിത്യചരിത്രം - ജി.ശങ്കരപ്പിള്ള

പാഠ്യപദ്ധതി തിയുടെ ഫലം (COURSE OUTCOME-CO)

- മലയാളഗദ്യത്തിന്റെ കരുത്ത് പരിചയപ്പെടാൻ കഴിയും.
- മലയാളത്തിന്റെ വിചാര രീതികൾ മനസ്സിലാക്കാം.
- നവോത്ഥാന ചിന്തകൾ അറിയാൻ കഴിയും.
- മതേതരത്വം, ശാസ്ത്രാവബോധം - ഇവ മനസിലാക്കാൻ കഴിയും ,
- മലയാളഭാഷ സംസ്കാരം,ഗദ്യത്തിന്റെ രീതിയും സൗന്ദര്യവും മനസ്സിലാക്കാം.
- മലയാളത്തിന്റെ ദൃശ്യപാരമ്പര്യമായ കഥകളി,കൂത്ത് , കൂടിയാട്ടം നാടകം, സിനിമ ഇവ പരിചയപ്പെടാൻ കഴിയും .
- സമൂഹവും ദൃശ്യകലയും തമ്മിലുള്ള ബന്ധം മനസ്സിലാക്കാം
- പുതുപ്രവണതകൾ പരിചയപ്പെടാൻ കഴിയും.

Appendix IV

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGYDEPARTMENT OF HINDI

Integrated M. Sc. Programme in Science

Common Course II A - Hindi COURSE STRUCTURE

I SEMESTER

Course - I - HINCCIIA01 - Short Story and Poetry Credit - 2

Objectives: To create a general awareness about different trends of Hindi Short Story and Poetry. It will help the students to get or in-depth understanding of the contemporary society as a whole and it will create cultural and humanitarian elements in them.

Module - I - Hindi Short Story

Meaning and definition of Short Story - Development of Hindi Short Story.

Prescribed Short stories:-

1. Sikka Badal Gaya - Krishna Sobti
2. Mazar Mein Ramdhan - Kailash Banvasi
3. Ulatbaansi - Kavita
4. Pachees Chauka Dedh Sau - Omprakash Valmiki
5. Hari Bindi - Mrudula Garg

Module - II - Hindi Poetry

Poetry - Defenition - Meaning - Development of Hindi Poetry - Different trendsof Contempoarary Hindi Poetry.

Prescribed Poems:-

1. Gurutwakarshan	-	Rajesh Joshi
2. Nadi aur Sabun	-	Gyanendrapati
3. Goonga Nahi Tha Main	-	Jayaprakash Kardam
4. Main Kiski Aurat Hoon	-	Savita Singh
5. Adivasi	-	Anuj Lugun

Books for Reference:-

1. Adhunik Hindi Kavita ka Vikas	-	Nandakishore Naval
2. Kavita ke Pate-Tikane	-	Vijaykumar
3. Hindi Kahani ka Itihas	-	Gopal Rai
4. Hindi kahani ka Vikas	-	Madhuresh

scheme of Examination - Total 100 Marks

Continuous Evaluation	-	50 Marks
First Internal	-	20 Marks
Second Internal	-	20 Marks
Seminar	-	10 Marks
End Semester Examination	-	**50 marks**

Time: 3Hrs

I.	12 Objective type questions	(0.5x12=6)
II.	Short answers: Out of 12 questions 6 to be answered	(4x6=24)
III.	Essays: Out of 4 questions 2 to be answered	(10x2=20)

II SEMESTER

Course - II - HINCCII02 - Prose **Credit -**

2

Objective:

To familiarize the students with various prose forms of Hindi Literature. Thiswill help to create a positive attitude towards language and literature.

Module - I

Development of prose forms - Different prose forms in Hindi - Essays -Biography - Autobiography - Memories - Sketches - Satire - Travelogue - One act play.

Module - II

Prescribed Prose forms:-

- Ek Kutta aur ek Maina - Hazariprasad Dwivedi
- Sadachar ka Tabiz - Harishankar Parsai
- Kahani Kala - I - Premchand
- Goongiya - Mahadevi Verma
- Thele par Himalay - Dharmaveer Bharti
- Ande ke chhilke - Mohan Rakesh

Books for Reference:

1. Hindi ka Gadya Sahitya - Ramchandra Tiwari
2. Hindi Sahitya ka Vaigyanik Itihas (Vol-II) - Ganapatichandra Gupt

Scheme of Examination - Total 100 Marks

Continuous Evaluation	-	50 Marks
First Internal	-	20 Marks
Second Internal	-	20 Marks
Seminar	-	10 Marks
End Semester Examination	**-**	**50 marks**

Time: 3Hrs

I. 12 Objective type questions	(0.5x12=6)
II. Short answers: Out of 12 questions 6 to be answered	(4x6=24)
III. says: Out of 4 questions 2 to be answered	(10x2=20)

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF ENGLISH AND FOREIGN LANGUAGES

Syllabus and Scheme of Examination of "Foreign Language 1 – German"
for Integrated M.Sc. Programme in Science Semester 1

Foreign Language 1 – German (FLG 10101) **Credits – 2**

Objectives:

- To create an awareness regarding the Importance of learning foreign languages particularly a language like German which gives Indian students an opportunity to purse higher studies in all the German speaking countries – in Germany, Switzerland and Austria.
- To teach the basic, simple vocabulary and sentence structure in German language.

Module – I

1. To greet and to say good bye, to introduce self and others, to speak about oneself and others, to learn the numbers up to 20, to say E-mail addresses and telephone numbers, to speak about countries and language:
2. To formulate simple questions and making simple statements, learning verbs and their conjugation patterns:
3. To speak about hobbies, professions.

Grammar:

1. Articles: der, die, das, verbs and personal pronouns, plurals of nouns, auxiliary nouns: haben and sein:
2. To speak about places and buildings, to ask about direction

Grammar:

1. Definite & indefinite articles, Articles of negation: kein, keine, kein: Imperative wih, Sie.

Module – II

1. Speaking about food and drink, to talk about shopping

Grammar:

1. Position of words in sentences, Nominative and accusative cases, verbs with Accusative case
2. To speak about time, family, how to make appointments, to excuse oneself, to make a telephone call

Grammar:

1. Giving details of time, the usage of prepositions: am, um, von.. bis possessive article “mein”, “deom” etc.. use of modal verbs in sentences:
   Modal verbs: Konnen, mussen, woollen:

3. To plan an event together, to speak about birthdays, to understand a text of an invitation, to order Something in a restaurant and make payment;

Grammar: To speak about dates: the preposition am, separable verbs, the preposition for personal pronouns in the Accusative- “mieh”, “dich”, past tense of “habens” and “sein”

Prescribed Text Book: NETZWERK Deutsch als Fremdsprache - A1 , Lesson 1 to 6

By: Stephanie Dengler, Paul Rusch, Helen Schmitz and Taja Sieber

Published in India by: GOYAL PUBLISHERS & DISTRIBUTERS Pvt. Ltd., 86. U.B. Jawahar Nagar, Delhi- 110 007 (INDIA)

Book for reference: Lernziel Deutsch. Deutsch als Fremdsprache, Grundstufe I, Lesson 1 to 6

Published by Mas Hueber Verlag, Munich, Germany-Special Indian Edition 1993
Printed by Udaya Printers, Madras – 600 003, India

Scheme of Examination

Continuous evaluation	: 50 marks
Semester End Examination	: 50 marks
Total	**: 100 marks**

Outcome of German Course offered to IMSc. Semester –I

Assuming regular attendance and independent study, the students should be able to learn the following in German language by the end of this course:

- Meet and greet a person, and state personal details
- Numbers 0-1000, telephone numbers/ mobile numbers.
- Alphabets, e-mail address.
- Days, Months and seasons.
- Professions and basic questions related to professions.
- Form filling (Online)
- Mode of transport
- Asking / telling the ways.
- Name the buildings and places.

Grammar –

- Verb conjugation
- Personal pronouns in nominative, accusative and dative cases.
- Definite and Indefinite Articles.
- Negative Article.
- Imperative for formal you.

ENVIRONMENTAL CHEMISTRY/ SCIENC SYLLABUS FOR INTEGRATED M Sc. PROGRAM OF DEPARTMENT OF APPLIED CHEMISTRY

Learning Objectives: (1) To teach the students the philosophy and chemistry of interactions occurs in natural environment based on mass and energy principles
(2) Applications of analytical determinations with respect to preservation and maintenance of human and natural environment.
(3) Theory and practice of environmental principles for a sustainable living of all
(4) Study of pollution control acts, rules and notifications of the country and world.

Learning Outcome: Students will be well leaned, oriented and trained for practicing environmental science, chemistry and technology in their carriers

UNIT 01 **Environment Protection Strategies and Measures**

Fundamental duties of every citizen of India Article 51-A (g). Stockholm conference on Human Environment in June 1972, Water (prevention and control of pollution) Act, 1974. Definitions: environment, pollution, forest, wildlife, rivers and streams,

UNIT 02 **Prevention and Control of Pollution- Definitions**

Effluent, sewage effluent, trade effluent, discharges, occupier, central and state boards for the prevention and control of water pollution, effluent samples, analysis results, industry inspections, prohibition of stream or well for the disposal of polluting matter, withdrawal of consent to industries, emergency measures to control pollution of stream and well.

UNIT 03 **Atmospheres and Natural Environment**

Atmosphere- Composition of unpolluted air - Layers of the atmosphere and Chemical Speciation in its different layers-Chemical and photochemical reaction in the atmosphere. Ozone layer. Reactions of atmospheric nitrogen, oxygen, ozone and water. Principle and method followed in air analyses.

UNIT 04 **Hydrosphere and its Significance:** importance of water- Hydrological cycle- classification of natural waters and natural processes that affect their composition, volume and mass flow calculations, inter phase mass transfer -Henry's law, mass transfer coefficient- acid-base equilibria, redox and complexation reactions in water. Mass balance equations, component mass balances, and environmental models- river and lake models.

UNIT 05 **Geosphere**: Introduction-definition of geosphere- kinds of minerals and rocks and their properties- rock cycle- stages of weathering-physical, chemical and biological aspects of weathering. Chemistry of ground water, hardness, ion exchange and reverse ion exchange, Hill – Piper- Trilinear plots.

REFERENCES

1. Pollution control acts, rules and notifications issued thereunder, central pollution control board, pollution control law series: PCLS/02/2010,CPCB, Delhi
2. Stanley E. Manahan(2017). Environmental Chemistry , 9th Edition, CRC Press Book, London.
3. APHA (2017). Standards Methods for the Examination of Water and Wastewater Analysis. 23Edition, APHA, Washington DC.
4. M. Harrison (2001). Pollution: Causes, Effects and Control. Fourth Edition, The Royal Society of Chemistry, Cambridge.
5. T. H. Y. Tebbutt (2004). Priciples of water quality control, Sixth edition, ISBN 0 7506 36580, Buttorworth-Heinemann.
6. A.W. Hounslow (1995). Water Quality Data –Analysis and interpretation, Lewis Publishers, Boca Raton

COM 10401 BASIC COMPUTER SCIENCE

Core/Elective: Core Credits: 2

Course Description

This course teach how to think like a computer scientist. Especially, how to combine some of the best features of Mathematics, Engineering, and Natural Science. The major emphasis of the course would be to develop the student's skills rquired for Problem-Solving; the ability to formulate problems, think creatively about solutions, and express a solution clearly and accurately.

Course Objectives

- To introduce the concept of computational thinking
- To get a firm foundation of computer science
- To hone problem solving skills in computer science
- To learn how to write effective scientific programs in Python

Course Content

MODULE 1: Computer Science and Computational thinking – Modern computer – Moore's law – Information and Data – Data types and data encoding: Numbers, text, pictures, sound – Data compression

Logic – Boolean logic: Writing propositions- Evaluating propositions- Applications of propositional logic – Solving problems: Problem definition- logical reasoning- decomposition – abstraction

MODULE 2: Algorithmic thinking: Algorithms – Software and programming languages – Modeling solutions: Activity diagrams – State diagrams – Introduction to Python - Data organization in Python: Objects and Identifiers- Numbers – Namespaces and modules- Container objects-Loop constructs-Functions-Python classes-Structure of Python

MODULE 3: Numpy: Arrays- 1D, 2D and higher dimensional arrays – Domestic input and output – Foreign input and output – Maxima and Minima – Sums and products – Simple statistics – Polynomials – Linear algebra: Solving linear systems of equations – more numpy and beyond

MODULE 4: Graphics – Two dimensional graphics: Simple figures – Cartesion plots – Polar plots – Error bars – Text and annotations – contour plots – Compound figures – Animations – Mandelbrot sets - Three dimensiona graphics: Three dimensional datasets – Visualization: Curve – Simple Surface – Parametrically defined surface

MODULE 5: Differential equations – Initial value problems: Basic concepts – Practical use – Two-point boundary value problems- Formulation of the boundary value problem- Linear eigen value problem - Delay differential equations – Logistic equation – Stochastic differential equations Partial differential equations: Initial-boundary value problems – Method of lines- Spatial derivatives: finite differentiating- Spectral techniques

TEXT BOOKS:

1. David Riley and Kenny A. Hunt, Computational Thinking for the Modern Problem Solver, Chapman & Hall/CRC Textbooks in Computing, 1 edn. 2014.

2. John M. Stewart , *Python For Scientists* , South Asian Edition, Cambridge India, 1 edn. 2015.

REFERENCES

1. John Zelle, Python Programming: An Introduction to Computer Science, 3 edn. 2016

2. Eric Matthes, Python Crash Course: A Hands-On, Project-Based Introduction to Programming, No Starch Press, 1 edn. 2015

3. Uwe Schöning, Logic for Computer Scientists, Birkhäuser, 1 edn. 1994

4. Dromey, How to Solve it By Computer, Pearson Education India, 1 edn. 2006

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DETAILED SYLLABUS OF SEMESTER I,II,III,IV

CORE

CHE 10101

ATOMIC STRUCTURE AND CHEMICAL BONDING

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Describe the major discoveries that led to the foundation of quantum mechanics	Understand
C.O. 2: Correlate the concepts of quantum mechanics toatomic structure	Apply
C.O. 3: Correlate the concepts of atomic structure toproperties of atoms	Analyse
C.O. 4: Apply the concept of atomic orbitals to buildmolecular orbitals	Apply
C.O. 5: Evaluate the structure and bonding of any molecule	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x									
C.O.2	x	x								
C.O.3	x	x								
C.O.4	x	x								
C.O.5	x	x								

UNIT – 1 **(10 hrs)**

Black body radiation, Planck's law, Hydrogen spectrum, Bohr's theory, its limitations, Photoelectric effect, Double slit experiment, Heisenberg's uncertainty principle and its significance, Wave-Particle duality, de Broglieequation. Limitations of classical mechanics in describing the properties of microscopic particles.

Semester 1

UNIT – 2 **(10 hrs)**

Schrödinger's wave equation, significance of ψ and ψ^2, Quantum numbers and their significance. 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 probabilitydiagrams.

UNIT – 3 **(8hrs)**

Quantization, Electronic Transitions, Quantum Theory, Atomic Energy States, Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number. Electronic energy level diagram and electronic configurations of hydrogen-like and polyelectronic atoms and ions. Excited states.

UNIT – 4 **(10 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, Lewis structure, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding
(σ andπ bond approach) and bond lengths, Ionic character in covalent compounds:
Bond moment and dipole moment.

UNIT – 5 **(10 hrs)**

Valence Bond theory, Hybridization, equivalent and non-equivalent hybrid orbitals. Bent's rule, 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. molecular orbitals, sigma and pi bonds, multiple bonding, Concept of Bond order, bond length, bond strength, bond energy, Formal charge, Molecular Electron Configurations, Metallic Bond: Qualitative idea of valence bond and band theories. Semiconductors and insulators, Van der Waal's forces, ion-dipole, dipole–dipole interactions, London forces, Hydrogen bonding; Effect of chemical forces on physical properties.

Recommended Text Books:

1. Lee, J.D. Concise Inorganic Chemistry, 5th Ed., John Wiley & Sons, 1999.
2. Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of InorganicChemistry, 3rd Ed., Oxford, 1994.
3. Atkins, P.W. and Paula, J. Physical Chemistry, 8th Ed., Oxford Press, 2006.
4. Day, M.C. and Selbin, J.Theoretical InorganicChemistry, 2nd Ed., ACS Publications,2002.
5. 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.
6. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4thd., W.H.Freeman & Company, 2006.
7. Housecroft, C. and Sharpe, G., Inorganic Chemistry, 4th Ed., Pearson,2012.
8. Levine, I. N. Physical Chemistry, 6th Ed., McGraw-Hill Education, 2008.

Semester 1

CORE/LAB

CHE 10102

QUANTITATIVE ANALYSIS LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Develop basic concepts of quantitative volumetric analysis.	Understand
C.O. 2: Estimate the amount of a given substance byacidimetry, alkalimetry and permanganometry.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1

I. Acidimetry and Alkalimetry

1. Strong acid- Strong base
2. Strong base –Weak acid
3. Strong acid-Weak base
4. Estimation of hardness of water

II. Redox Titration (Permanganometry)

1. Estimation of Oxalicacid
2. Estimation of Mohr'ssalt
3. Estimation of Ferrousiron
4. Estimation of Manganese dioxide in pyrolusite

Recommended Text Books:

1. Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.,PearsonsEducation Ltd.
2. Laboratory Manual, CHE 10102, Department of Applied Chemistry, CUSAT.

Semester 1

CORE

CHE 10201

PERIODICITY, NUCLEAR CHEMISTRY, ACID BASE CHEMISTRY AND METALLURGY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Correlate the physical and chemical properties of elements basedon their periodic classification	Analyze
C.O.2: Analyse the properties, stability, mode of decay and kinetics of a given nucleus/nuclear process	Apply
C.O.3. Describe the radioactivity phenomena and its applications	Understand
C.O.4: Compare the strength of various acids and bases	Apply
C.O.5: Explain the occurrence of minerals and metallurgical principles for isolation and purification	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x								
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					
C.O.5	x	x			x					

UNIT – 1 **(10 hrs)**

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, Electron negativity,Electron Affinity, Polarizability and polarizing power, Relative orbital energies and overlap, Trends associated with properties – Physical and chemical, Anomalies in periodic properties. Predicting Chemistry of super heavyelements.

UNIT – 2 **(14 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.

UNIT – 3 **(8hrs)**

Transuranium elements: Synthesis, separation and properties of transuranium elements.Radioisotopes:Co-precipitation,ion-exchange,solventextraction as a tracer, Synthesis of labeled compounds (any two), isotopic dilution and radiopharmaceuticals. Neutron activation analysis, Principles of determination of age of rocks and minerals, radio carbon dating principles, Isotope dilution and neutron activation analysis.

UNIT – 4 **(8 hrs)**

Acid Base concepts, Bronsted-Lowry definition, Lux Flood Definition, Solvent system definition, Lewis Definition, Usanovich Definition, Generalized concept, Measures of acid base concept, Acid Base anomalies, Pearson's HSAB concept, acid-base strength and hardness and softness, Symbiosis, theoreticalbasis of hardness and softness, electronegativity and hardness.

UNIT – 5 **(8 hrs)**

Occurrence of metals based on standard electrode potential, methods of concentration of ores, reduction to free metal, electrometallurgy, hydrometallurgy, and synthesis of ultrapure elements. Refining of metals, electrolytic, ion exchange, zone refining, vapour phase refining and oxidative refining. Thermodynamics of the oxidation of metals to metaloxides- Ellinghamdiagrams. Extractive metallurgy of U, Th, Ti.

Recommended Text Books:

1. Mingos, D. M. P., Essential trends in inorganic chemistry, Oxford Universitypress 1998.
2. Wulfsberg, G., Inorganic Chemistry, VIVA,2002.
3. Greenwood, N. N., Earnshaw, A., Chemistry of Elements, MaxwellMacmillan 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. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4th Ed., W.H. Freeman & Company,2006.
7. Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of InorganicChemistry, 3rd Ed., Oxford, 1994.
8. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed.,Pearson, 2014.
9. Sharma, B. K., Industrial Chemistry (including Chemical Engineering),GOEL Publishing House,1997.
10. Arnikar, H. J., Essentials of Nuclear Chemistry, Wiley Eastern Ltd., NewDelhi, 1982.

ORE/LAB

CHE 10202

INORGANIC QUALITATIVE ANALYSIS LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Develop basic concepts of inorganic qualitative analysis	Understand
C.O. 2: Identify acid radicals and basic radicals from a given sample mixture	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1 **(96 hrs)**

Systematic qualitative analysis of mixtures containing two acid and two basic radicalsfrom 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^{2-} , NO^{-} , F^{-}, Cl^{-}, $C\,O^{2-}$, $CH\,COO^{-}$, PO^{3-} , CrO^{2-}

Recommended Text Books:

1. A.I. Vogel, A Text Book of Qualitative Inorganic Analysis, Longman,1966.
2. Laboratory Manual, CHE 10202, Department of Applied Chemistry,CUSAT.

CORE

CHE 10301

INTRODUCTORY ORGANIC CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Assign the nomenclature of simple organic molecules following IUPAC rules	Apply
C.O.2: Illustrate different bonding models to predict the three dimensional structure of molecules.	Analyse
C.O.3: Apply the concepts of isomerism and analyse the conformation and configuration of organic molecules.	Analyse
C.O.4: Describe the different types of organic reactions	Understand
C.O.5: Develop an insight into the importance of organic chemistry in life	Understand

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x								
C.O.2	x	x								
C.O.3	x	x								
C.O.4	x	x								
C.O.5	x	x								

UNIT – 1 **(6 hrs)**

Nomenclature of organic compounds. Rules of IUPAC system of nomenclature of common organic compounds – alkanes, alkenes, alkynes, cycloalkanes, bicycloalkanes, alkyl halides, alcohols and phenols. Aldehydes, ketones, carboxylic acids and its derivatives, amines, nitro compounds, heterocyclic compounds.

UNIT – 2 **(10 hrs)**

Structure and Models of bonding: Study of Lewis Structures, Formal Charge, VSEPR, Hybridization, localised σ and π bonds, polar covalent bonding, Bond dipoles, molecular dipoles and quadrupoles, polarizability, Resonance, Bond Lengths and Bond energy.

UNIT – 3 **(10 hrs)**

Stereochemistry: 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 - determination of configuration.

Conformational analysis: Strain in molecules, acyclic molecules, cyclohexane, substituted cyclohexanes- A values.

UNIT – 4 **(12 hrs)**

Basic introduction to Organic reactions: Classification and an overview of organic reactions. Electron pushing diagrams. Basics of reaction coordinate diagrams, intermediates, transitions states, exothermic and endothermic reactions, activation energy, rates of reactions and rate determining step. Hammond's postulate. Nucleophilic substitutions - S_N1, S_N2, substitutions on aromatic carbon, Addition reactions - polar and non-polar addition - addition of Bromine and hydrogen halides to double bonds - Markownikoff's rule and peroxide effect., Elimination - E1, E2, E1cb, pyrolytic elimination. Basic introduction to rearrangements and Pericyclic Reactions.

UNIT – 5 **(10 hrs)**

Organic Chemistry in life: Natural products (structure and classification) – Terpenes, Steroids and alkaloids. Biomolecules (structure and function):

carbohydrates, amino acids, proteins and nucleic acids. Pharmaceuticals and Drugs, Dyes and Chemistry of Vision. Introduction to polymer science – Monomers and Polymerisaton. Mechanisms of Radical and condensation polymersiations.

Recommended Text Books:

1. Clayden J., Greeves, N. Warren, S., Organic Chemistry (2 Ed), OxfordUniversity Press, 2001.
2. Bruice, P.Y. Organic Chemistry, 7th Ed., Prentice Hall Inc., 2013.
3. Morrison, R.T. Boyd, R.N. and Bhattacharjee, S.K. Organic Chemistry, 6th Ed., Pearson Education Inc., 2014.
4. McMurry, J. Organic Chemistry, 5th Edition, Brooks/Cole, 2000.
5. March, J., Smith, D., March's Advanced Organic Chemistry:Reactions, Mechanisms and Structure, 7th Ed., Wiley, 2013
6. Carroll, F.A. Perspectives on Structure and Mechanism in Organic Chemistry,2nd Ed., Wiley, 2010.

CORE/LAB

CHE 10302

ORGANIC QUALITATIVE ANALYSIS LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1:Identify the functional group(s) present in a given organic compound	Understand
C.O.2:Categorize the unknown organic compound based on functional groupanalysis and prepare the corresponding derivative	Analysis

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1 **(96 hrs)**

Identification of simple organic compounds

Preparation of derivatives

Recommended Text Books:

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. Dey, B.B. Sitaraman, M.V. and Govindachari, T.V. Laboratory Manual ofOrganic Chemistry, 3rd Ed., Viswanathan, 1957.
3. Furniss, B.S. Hannaford, A.J. Smith, P.WG. Tatchell, A.R. Vogel's Textbook ofPractical Organic Chemistry, 5th Ed., Longman, 1989.
4. Mann, F.G. Saunders, B.C. Practical Organic Chemistry, 4th Ed., PearsonEducation India, 2009.
5. Clark, H.T. A handbook of organic analysis, Longman, 1966.
6. Laboratory Manual, CHE 10302, Department of Applied Chemistry, CUSAT.

CORE

CHE 10401

INTRODUCTORY PHYSICAL CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Differentiate the properties of real gases from those of a perfect gas, and construct an equation of state that describes their properties.	Apply
C.O. 2: Predict changes in thermodynamic parameters during a processand predict the spontaneity.	Apply
C.O. 3: Apply the laws of chemical kinetics and photochemistry to calculate rate/ rate constants/quantum yield of different types of reactions.	Apply
C.O. 4: Understand the details of the structure of solid surfaces and the extent to which a surface is covered and the variation of the extent of coverage with the pressure and temperature	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					

UNIT – 1 **(8 hrs)**

Real gases- Deviation from ideal behavior- Compressibility factor, Van derWaals equation, Virial equation, PV isotherms, Continuity of states, Law ofCorresponding states, Critical phenomena and critical constants.

UNIT – 2 **(10 hrs)**

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- Changes during isothermal and adiabatic reversible and irreversible processes. Joule Thomson effect- Inversion temperature, Application of J.T effect - Liquefaction of gases.

Entropy and free energy as criteria for spontaneity and equilibrium. Nernst Heat theorem and Unattainability of absolute zero.

UNIT – 3 **(6 hrs)**

Theories of acids and bases- Arrhenius Theory, Lewis theory and Bronsted Theory, Hard and soft acids, pH, PK_a, PK_b, Ionic product of water, Common ioneffect, Solubility product, Acid strength, Degree of hydrolysis of salts, Buffer solutions, Mechanism of buffer action, Henderson equation.

UNIT – 4 **(12 hrs)**

Rate laws, Order and molecularity, Zero, first, second and third order reactions- Integration of rate laws, Half-life period, Temperature dependence of rate constant- Arrhenius equation Photochemistry- Photochemical laws, Beer Lambert Law, Quantum yield, Jablonski Diagram-Photophysical and photochemical processes, Fluorescence, Phosphorescence-,Chemiluminescence,Bioluminescence,Photosensitisation,Photosynthesis

UNIT – 5 **(12 hrs)**

Adsorption- Physisorption and chemisorption, Adsorption 16 Isotherms- Langmuir, Freundlich and BET isotherms (Qualitative approach), Applicationof isotherms for surface area determination, Catalysis- homogeneous and heterogeneous (introduction) Enzyme catalysis- Michael Menton equation. Colloids- Lyophilic and Lyophobic colloids, Preparation of colloids, Kinetic, optical and electrical properties, Electrical double layer Models for double layer: Heimboltz, Gouy Champman and Stern, Zeta potential. Stability of colloids, Protective colloids- Gold number, Flocculation, Hardy Schulze rule, Surfactants, micelles, Critical miscelle concentration, Factors affecting CMC Reverse miscelle, Donnan membrane equilibrium, Dorn effect, Sedimentation potential and streaming potential, Emulsions, Gels, Sols.

Recommended Text Books:

1. Peter Atkins and Julio de Paula, Physical Chemistry, Oxford University Press, 8th and 10th Edn, 2017.
2. D.A McQuarrie, J.D Simon, Molecular Thermodynamics, Viva Student Edn. 2010.
3. I.N Levine, Physical Chemistry, McGraw Hill, Indian Edn, 2011.
4. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York.
5. K. J. Laidler, Chemical-Kinetics, McGraw Hill, New York.

CORE/LAB

CHE 10402

PHYSICAL CHEMISTRY LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Verify the concepts and laws in physical chemistry	Evaluate
C.O.1: Execute and perform experiments based on pH metry, potentiometry, conductometry and colorimetry to quantify andobtain other physical properties of the chemical species	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1 **(96 hrs)**

1. pH METRY

   Strong acid X strong base, Strong acid X weak base, Weak acid X Strong base

2. POTENTIOMETRY

   Strong acid X strong base, Strong acid X weak base, Weak acid X Strong base, $KMnO_4$ X Fe2+

3. CONDUCTOMETRY

   Strong acid X strong base, Strong acid X weak base, Weak acid X Strong base

4. COLORIMTERY

   Estimation of iron, chromium, nickel, Manganese, Copper, phosphate in soft drinks

Recommended Text Books:

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.,KrishnaPrakashan, 2016.
3. Laboratory Manual, CHE 10402, Department of Applied Chemistry, CUSAT

Syllabus

for

Five Year Integrated MSc

(Biological Sciences)

Centre for Integrated Studies

Cochin University of Science and Technology

(with effect from 2021-2022)

STRUCTURE AND SCHEME OF THE COURSE

SEMESTER – V

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
BIO10501	Plant Diversity I (Algae/Fungi/Bryophytes/Pteridophytes/Paleobotany)	C	50	50	100	3
BIO10502	Non-chordates	C	50	50	100	3
BIO10503	Plant Diversity II (Gymnosperms & Angiosperms)	C	50	50	100	3
BIO10504	Chordates	C	50	50	100	3
BIO 10505	Plant Lab 1	C	100	-	100	2
BIO 10506	Animal Lab 1	C	100	-	100	2
BIO 10507	Open Ended Lab – I	C	100	-	100	2
BIO 10508	Bioinformatics & Biostatistics		50	50	100	2
BIO10509	Animal Forms and Functions		50	50	10	2
	Total		**600**	**300**	**900**	**22**

SEMESTER – VI

Course Code	Name	C/E	Marks Distribution			Credit
			Continuous evaluation	End semester	Total	
BIO 10601	Microbiology	C	50	50	100	3
BIO 10602	Angiosperm (Anatomy/Physiology/Embryology)	C	50	50	100	3
BIO 10603	Evolution and Developmental Biology	C	50	50	100	3
BIO 10604	Parasitology and Immunology	C	50	50	100	3
BIO 10605	Plant Lab 2	C	100	-	100	2
BIO 10606	Animal Lab 2	C	100	-	100	2
BIO 10607	Open Ended Lab – II	C	100	-	100	2
BIO 10608	Food, Nutrition and Health	C	50	50	100	2
BIO 10609	Plant Tissue culture	C	50	50	100	2
	Total		**600**	**300**	**900**	**22**

SEMESTER – VII

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
BIO 10701	Cellular metabolism	C	50	50	100	3
BIO 10702	Cell Biology	C	50	50	100	3
BIO 10703	Enzymology	C	50	50	100	3
BIO 10704	Molecular Biology	C	50	50	100	3
BIO 10705	Biochemistry Lab	C	100	-	100	2
BIO 10706	Cell and Molecular Biology Lab	C	100	-	100	2
BIO 10707	Open Ended Lab I	…	…..	…..	…..	…..
BIO 10708	Genetics	E	50	50	100	2
BIO 10709	Breeding and Culture techniques	E	50	50	100	2
	Total		**500**	**300**	**800**	**20**

SEMESTER – VIII

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	**End semester**	**Total**	**Credit**
BIO 10801	Advanced Microbiology	C	50	50	100	3
BIO 10802	Plant physiology and biochemistry	C	50	50	100	3
BIO 10803	Animal Physiology and Endocrinology	C	50	50	100	3
BIO 10804	Ethology and Chronobiology	C	50	50	100	3
BIO 10805	Microbiology Lab	C	100	-	100	2
BIO 10806	Plant and Animal Physiology Lab	C	100	-	100	2
BIO 10807	Open Ended Lab II	….	…..	….	….	…
BIO 10808	Research Methodology / Bioethics/Biosafety/IPR	E	50	50	100	2
BIO 10809	Biophysics and Bioinstrumentation	E	50	50	100	2
	Total		**500**	**300**	**800**	**20**

SEMESTER – IX

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
BIO 10901	Immunology	C	50	50	100	3
BIO 10902	Genetic Engineering	C	50	50	100	3
BIO 10903	Computational Biology	C	50	50	100	3
BIO 10904	Environmental Biology	C	50	50	100	3
BIO 10905	Immunology Lab	C	100	-	100	2
BIO 10906	Genetic engineering and Computational Biology Lab	C	100	-	100	2
BIO 10907	Open Ended Lab III	C	100	100	100	2
BIO 10908	Genomics and Proteomics	E	50	50	100	2
BIO 10909	Molecular Taxonom	E	50	50	100	2
	Total		**600**	**400**	**900**	**22**

SEMESTER-X

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
BIO 11001	Innovation and Entrepreneurship for Biologists	E	-	50	50	2
BIO 11002	Dissertation	C	-	200	200	16
	Total			**250**	**250**	**18**

PROGRAM OBJECTIVES

The Integrated M. Sc. Biology program describes accomplishments that graduates are expected to attain within three to five years after graduation

- The program will ensure an up-to-date level of understanding of the concept of basic and applied Biology.
- The program aims to articulate the importance of biology in terms of environment, medicine, agriculture, and food and use them for the development of the nation to compete at a global level.
- The program will inculcate the students with professional and research ethics at their working place.
- The program would enable the students to address the major concerns of our society in a multidisciplinary way (conserving biodiversity, public health, safety, cultural and societal development).

PROGRAM OUTCOMES (POS)

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

PO1. Describe 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)- (Understand level).

PO2. Show proficiency in performing various basic and advanced laboratory techniques employed in Biology in academia and industries (Apply).

PO3. Design and conduct biological experiments, analyse and interpret experimental data and perform troubleshooting if necessary (Create).

PO4. Identify a research problem using a literature survey, formulate a hypothesis, develop a research plan, execute the research plan, write the project report and communicate effectively through written, oral and visual methods (Remember).

PO5. Analyze and interpret large-scale biological datasets such as phylogenetic analysis, protein structure prediction, elucidating and quantifying various biomolecules, estimate various metabolites, estimating enzyme kinetics, mutation profiling, nucleotide and protein sequence analysis and NGS analysis (Analyze).

PO6. Assess various plant /animal/microbial resources, biological techniques to develop entrepreneurship in the biological industry (Evaluate).

Detailed Syllabus of Biology

SEMESTER V

BIO 10501- PLANT DIVERSITY –I (Algae/Fungi/Bryophytes/Pteridophytes/Paleobotany) (3C= 48 hrs)

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 concept 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 palaeobotanical 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 in understanding plant diversity, economic values, the taxonomy of lower groups of plants.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain why fungi is 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: Diffrentiate 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	Understand
C.O. 6: Discuss the significance of paleobotany in terms of understanding the evolution and emergence of plant diversity	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2	x					
C.O.3					x	
C.O.4	x					
C.O.5	x					
C.O.6	x					

MODULE I **(10 hrs)**

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 **(10 hrs)**

Fungi: Salient features, Morphology, reproduction, life cycle, evolutionary trends. Distinguishing features of fungi and why is it grouped in a separate kingdom, Classification based on Ainsworth. Distinguishing characters of different classes of fungi representing the following genera, Myxomycotina-General characters, Phycomycetes-Phytophthora, Ascomycetes-Penicillium & Xylaria, Basidiomycetes-Agaricus & Puccinia, Deuteromycetes-Cercospora. Economic importance of Fungi, Fungi as a pathogen, brief account of the following fungicides-Bordeaux mixture, Lime sulfur, Tobacco devotion, Neem cake, and oil.

Lichens: General account; the structure, reproduction and life cycle of Usnea, and economic importance

MODULE III **(10 hrs)**

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

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MODULE IV **(10 hrs)**

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 **(8hrs)**

Paleobotany: 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 Delhi2.
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 – edarnath, Ramnath – Meerut.
6. Smith G.M. (1955) - Cryptogamic Botany – Vol.II – Mc Graw Hill Co. New Delhi
7. Sporne K. R. (1966) - Morphology of Pteridophytes - Hutchin University Library London
8. Sporne K. R. (1967) - Morphology of Gymnosperms - Hutchin University Library, London
9. Vashista B. R. (1993) - Pteridophyta – S. Chand and co. New Delhi
10. Vashista B. R. (1993) Gymnosperms - S. Chand and co. New Delhi
11. Andrews H.N. (1967) - Studies on Palaeobotany – C. J. Felix.
12. Arnold C. A (1947) - Introduction to Palaeobotany - McGraw Hill Co. New Delhi.

BIO 10502- NON-CHORDATA **(C=48 hrs)**

Course description: The course will help the students to understand the features of Kingdom

Animalia and 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.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**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:Calssify 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
C.O. 6: Improve collaborative learning and communication skills through practical sessions, teamwork, group discussions, assignments and projects.	Apply

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4					x	
C.O.5	x					
C.O.6		x				

MODULE I **(10 hrs)**

Basis of classification of multicellular animals: Cleavage; Germ layers; Symmetry; Body cavity; Concept of Protostomia *vs.* Deuterostomia.

MODULEII **(10 hrs)**

General characteristics and classification (up to Class/subclass level) of Major Phyla: Protozoa; Porifera; Cnidaria; Ctenophora; Platyhelminthes, Annelida, Arthropoda; Mollusca, Echinodermata.

MODULE III **(10 hrs)**

A general account of structure and reproduction of *Paramecium*; *Sycon*; *Obelia*; *Aurelia*; Planaria (*Dugesia*); *Fasciola*; *Hirudinaria*; *Pila*; Prawn; Starfish: *Peripatus*; *Limulus*; *Balanoglossus*.

MODULE IV **(10 hrs)**

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 **(8 hrs)**

Reproduction in Protozoans; Theories on the origin of Metazoa; 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. Barrington: Invertebrate Structure and Function (1967, Nelson)
3. Moore: An introduction to the invertebrates (2001Cambridge)
4. Ekambaranath Ayar: A manual of Zoology, Part I – Invertebrata, (1973, S. Vishwanathan)
5. Kotpal, Agarwal and Khetrapal: Modern Textbook of Zoology: Invertebrate, (1976, Rastogi)
6. Marshall: Parker and Haswell Textbook of Zoology, Vol. I (7th ed. 1972, Macmillan)
7. Nigam: Biology of Non-chordates (1985, S. Chand)
8. Jordon and Verma: Invertebrate Zoology (1995, S. Chand)
9. Millar and Harley: Zoology (6th ed. 2005, Brown)
10. Garey, J. R. and Schmidt-Rhaesa, A. The Essential Role of "Minor" Phyla in Molecular Studies of Animal Evolution. AMER. ZOOL., 38:907-917 (1998).

BIO 10503- PLANT DIVERSITY II (Gymnosperms and Angiosperms) (3C= 48 hrs)

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, tribals, ethenic groups, their nutritive and medicinal value.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**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

MAPPING of CO’s and PO’s

Programme Outcomes						
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4	x					
C.O.5	x					

MODULE I (10 hrs)

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 (10 hrs)

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 (10 hrs)

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 (8 hrs)

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 (10 hrs)

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,

REFERENCE

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 Text Book of Economic Botany; Ane Books Pvt. Ltd.
4. Kapoor LD, 2001 Hand Book 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.

BIO 10504- CHORDATA **(3C= 48 hrs)**

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 notochord. 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.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**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 in relation to function (circulatory, nervous and skeletal system of	Analyse

chordates).	
C.O. 5: Discuss the pattern of vertebrate evolution, organization and functions of various systems.	Remember
C.O. 6: Evaluate the survival advantages of chordates based on adaptive features in various habitat (marine, freshwater and terrestrial ecosystems)	Evaluate
C.O. 7: Explain the characteristic features of various structures in relation to function	Understand

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4					x	
C.O.5				x		
C.O.6						x
C.O.7	x					

MODULE I **(10 hrs)**

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 **(10 hrs)**

Functional morphology of *Branchiostoma*, *Petromyzon*; Mullet, Frog; *Calotes*, fowl and rabbit.

MODULE III **(8 hrs)**

Adaptive radiation in vertebrates: Aquatic; Terrestrial; Aerial; Arboreal; Fossorial.

MODULE IV **(10 hrs)**

Evolution of aortic arches; jaw suspensorium; respiratory organs (gills, skin, lungs, air sacs, accessory respiratory organs), kidney, skull in reptiles; brain (cerebral hemisphere, cerebellum).

MODULE V **(10 hrs)**

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 Text Book 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)
12. Young: The Life of Vertebrates (3rd ed 2006, ELBS/Oxford)
13. Young: The Life of Mammals (1975 Clarendon)

BIO 10505- PLANT LAB 1 **(2C= 32 hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Identify and Evaluate the vegetative and reproductive structures of fungi, Algae, Bryophytes, and Pteridophytes	Remember/Evaluate
C.O. 2: Apply taxonomic protocols and Classify algae, fungi, bryophytes, pteridophytes	Understand /Apply
C.O. 3: Diffrentiate 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	Create
C.O. 6: Use bioinformatics tools for DNA/gene analysis of plants and Interpret the phylogenetic relationships	Apply

MAPPING of CO's and PO's

Programme Outcomes

Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					x
C.O.2	x	x				
C.O.3					x	
C.O.4				x		
C.O.5						x
C.O.6					x	

<u>Plant Diversity</u> (Algae/Fungi/Bryophytes/Pteridophytes/Paleobotany)

1. Study of vegetative and reproductive structures of Nostoc, Chlamydomonas (electron micrographs), Oedogonium, Vaucheria, and Polysiphonia through permanent slides.
2. Rhizopus and Penicillium: Asexual stage from temporary mounts and sexual structures through permanent slides.
3. Phytophthora: Specimens/photographs
4. Puccinia: Uredial and telial stage TS, stage identification with permanent slides.
5. Agaricus: Specimens of button stage and full-grown mushroom; LS of gills.
6. Lichens: Study of growth forms of lichens (crustose, foliose and fruticose)
7. Riccia- Habit- V.S of the thallus, VS through archegonia, antheridia and sporophyte
8. Marchantia- Habit, thallus VS, male receptacle and female receptacle-entire and VS, thallus gemma- entire and VS, Sporophyte VS
9. Anthoceros: Habit- VS of thallus and sporophyte
10. Funaria- Habit V.S. of the archegonial cluster, Antheridial cluster and Sporophyte
11. Psilotum -External features, Stem T.S., Synangium T.S
12. Selaginella - Habit, stem & rhizophore T.S, V.S of strobilus
13. Pteris - Habit, Rachis T.S Sporophyll T.S, Prothallus
14. Marselia - Habit, Rhizome and Petiole T.S, Sporocarp T. and V.S
15. Identification and critical notes on fossil forms (Fossil slides).

<u>Gymnosperms and Angiosperms</u>

1. Cycas- T.S of leaf, T.S. of coralloid root, Male and female cone, ovule (LS)
2. Pinus- T.S. of the stem, T.S. of needle, male and female cone VS
3. Gnetum-Habit, stem T.S, (young and mature), leaf T.S, male and female strobilus, V.S of the male and female cone, ovule V.S and seed.
4. Study on various types of inflorescences, flowers and fruits with a vivid record of practical work.
5. Draw a labeled diagram of the habit, floral parts, L S of flower, T S of ovary, floral diagram, floral formula and describe the salient features of the member in technical terms

of the families: Annonaceae, Rutaceae, Cucurbitaceae, Rubiaceae, Asteraceae, Sapotaceae, Sapotaceae, Asclepiadaceae, Verbenaceae, Euphorbiaceae, Orchidaceae and Poaceae.

6. Students must submit practical records, Herbarium sheets (25 Nos:) and Field books at the time of practical examination.
7. I identify the economic products obtained from the plants mentioned under Economic Botany
8. Critical notes on plants of ethnobotanical relevance mentioned in the syllabus.

Biostatistics and Bioinformatics

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.

BIO 10506- ANIMAL LAB 1 **(2C= 32 hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Identify and Analyze various anatomical structures of non-chordates and chordates (mouthparts, respiratory system, appendages etc)	Analyze
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 and Analyze
C.O. 4: Compare the members based on anatomical features in relation to function (circulatory, nervous and skeletal system of chordates) of non-chordates and non-chordates.	Analyse
C.O. 5: Predict protein sequence based on gene sequence	

	Analysis
C.O. 6: Design analogues of enzyme inhibitors / catalytic sites of enzyme to aid in *in silico* drug discovery	Create
C.O. 7: Explain the characteristic features of various structures in relation to function	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1					x	
C.O.2					x	
C.O.3				x	x	
C.O.4					x	
C.O.5					x	
C.O.6			x			
C.O.7	x					

Non-Chordata

1. Nereis - parapodium
2. Earthworm – body setae, nervous system
3. Scales of butterfly wing
3. Cockroach – mouth parts /salivary gland/nervous system
4. Honey bee – 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

Chordata

1. Branchiostoma- External features; Mounting of the oral hood, velum and pharyngeal wall Study of thefollowing 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 cycloid and ctenoid scales; mounting of chromatophores of fish; study of different types of feather: Contour, filoplume and down feathers
3. Vascular system- Heart and afferent and efferent branchial vessels of Mystus/ *Cirrhinus sp.;* Arterial andvenous systems of rat
4. Respiratory system: Accessory respiratory organs of *Heteropneustes, Channa, Clarias*
5. Nervous system of a fish
6. Histology of tooth, tongue, esophagus, 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, Myxine
    2. Chondrichthyes: Scoliodon, Sphyrna, Torpedo, Pristis
    3. Osteichthyes: Protopterus, Exocetus, Hippocampus, Syngnathus, Tetradon, Diodon, Amia, Anabas, Ophiocephalus, Clarias, Heteropneustes, Catla, Labeo,
    4. Amphibia: Ichthyophis, Axolotl larva, Amphiuma,Proteus, Pipa, Rhacophorais Hyla
    5. Reptilia: Turtle, Chameleon, Draco, Uromastix, Varanus, Calotes, Iguana, Mabuya, X Natrix, Naja, Vipera, Alligator
    6. Aves: Apteryx, Struthio, Aptenodytes, Francolinus, Tyto alba, Dinopium, Milvus, Corvus, Pavo, Eudynamys, Passer, Psittacula, Anas, Grus
    7. Mammalia: Ornithorhynchus, Tachyglossus, Macropus, Manis, Erinaceus, Pteropus, Lemur, Loris, Bradypus, Phoca, Lutra, Equus caballus, Camelus, Capra, Bos

Animal Forms and Functions

1. Study and mounting of cephalic appendages of Palaemon
2. Dissection of the digestive system of Palaemon and mounting of Hastate plate

3. Study of mouthparts of Periplaneta americana
4. Dissection of the alimentary canal of Periplaneta americana
5. Internal transport: Dissection of afferent and efferent branchial arteries of Mystus
6. Nervous system, receptors and sense organs
7. Dissection of the nervous system of Palaemon
8. Mounting of statocyst of Palaemon
9. Dissection of 5th, 7th, 9th, and 10th cranial nerves of Mystus
10. Permanent preparation of gemmules of sponges
11. Study of the following through permanent slides/museum specimens:Conjugation in Paramecium, Sporocyst of Fasciola with developing Redia, Cercaria and Metacercaria larvae, Trochophore larva, Nauplius and Zoea larvae, Bipinnaria, Auricularia and Pluteus larvae, Tornaria, Ammocoetes and Tadpole (frog); Axolotl.

BIO 10507- OPEN END LAB I (2C= 32hrs)

BIO 10508- BIOSTATISTICS AND BIOINFORMATICS (2C= 32 hrs)

Course description: This course offers an overview of fundamental concepts of d 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.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the basic concepts of Bioinformatics and Biostatistics and their various applications in different fields of biological sciences	Understand
C.O. 2: Calculate the variability (standard deviation, standard error, coefficient of variance) and hypothesis testing (Z-test, t-Test, chi-square test)	Analyse
C.O. 3: List various biological databases – nucleic acids, protein sequence, metabolic pathways and small molecule	Remember
C.O. 4: Analyse gene sequence and pinpoint mutations	Analyze
C.O. 5: Predict protein sequence based on gene sequence	Apply
C.O. 6: Interpret the phylogenetic relationships	Apply
C.O. 7: Design analogs of enzyme inhibitors / catalytic sites of enzyme to aid in *in silico* drug discovery	Create

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3				x		
C.O.4					x	
C.O.5		x				
C.O.6		x				
C.O.7			x			

MODULE I **(8 hrs)**

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. 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 II **(5 hrs)**

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 III **(6 hrs)**

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, Approach of Comparative Biology based on sequence comparison - The basic idea of sequence comparison (algorithms not required) - idea of scoring matrices

MODULE IV **(6 hrs)**

The Blast search engine - important features - Idea of Multiple sequence alignment. Proteomics: Basic ideas of Protein Structure prediction- Concept of Homology Modeling- Idea of Molecular

Phylogenetics - 'advantages and computational procedure (only description of the use of a package such as Phylip). Basic concepts of computer Aided, Drug. Discovery.Autodock, ADME, Structure-function relationship.

MODULE V **(7 hrs)**

Bioinformatics tools: (i) Molecular Visualization Software - Rasmol (Basic features only)- (ii) ORF finding (iii) gene finding, (iii) BLAST (iv) Hydrophobicity Prediction (v)Single Nucleotide Polymorphism (SNP) prediction using GENSNIP, Central Drug Research Institute

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
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4. Arthur. M. Lesk (2000) Introduction to Bioinformatics, Oxford publishers.
5. Bajpai, P. K. (2008) Biological instrumentation and methodology. S. Chand and Company Ltd.
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7. Collins H. and Pinch, T. (1993) The Golem: What everyone should know about Science. Cambridge university press.
8. Mount, D. W. (2005). Bioinformatics: Sequence and Genome Analysis. CBS Publishers and Distributors Pvt. Ltd., Delhi
9. Debbie Holmes, Peter Moody and Diana Dine. (2006) Research methods for the biosciences,International students' edition. Oxford university press.
10. Gieryn, T.F. (1999) Cultural Boundaries of Science. University of Chicago press
11. Graeme. D. Ruxton and Nick Colegrave. (2006) Experimental design for the life sciences, 2nd edition. Oxford University Press.
12. Gurumani. Research Methodology. M.J.P.Publishers, Chennai, 600 005
13. Keith Wilson and John Walera. (2008) Principles and techniques of biochemistry and Molecular Biology. Cambridge University Press.

BIO 10509- ANIMAL FORMS AND FUNCTIONS **(2C= 32 hrs)**

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 protochordate, 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.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain comparative account of the different vertebrate systems	Understand
C.O. 2: Describe the evolution of the heart, modification in aortic arches, the structure of respiratory organs used in aquatic, terrestrial and aerial vertebrates; and digestive system and its anatomical specializations with respect to different diets and feeding habits.	Understand
C.O. 3: Discuss the evolution of the brain, sense organs and excretory organs to a complex, highly evolved form in mammals	Understand
C.O. 4: Evaluate the structure and functions relationship of animals which furnish with survival advantages in a habitat	Evaluate

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4						x

MODULE I **(6 hrs)**

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 **(6 hrs)**

Respiratory Organs, Structure and function of gills, trachea, book lungs and vertebrate lungs.

MODULE III **(6 hrs)**

Circulatory systems: Pattern of circulation in non-chordates and chordate, hemocoel, open and closed circulatory systems, the difference in chambers, evolutionary significance.

MODULE IV **(6 hrs)**

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 **(8 hrs)**

Reproduction Types of asexual reproduction: fission, regeneration and parthenogenesis, Sexual reproduction: primary and accessory sex organs and their functions

REFERENCES

1. Miller & 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 & Haswell: Text Book 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 & Row).
9. Schmidt Nielson: Animal Physiology (5th ed. 2005, Cambridge)
10. Hoar: General and Comparative Physiology (7th ed. 2005)
11. Arms and Camp: Biology (4th ed. 1995)

SEMESTER VI

BIO 10601- MICROBIOLOGY **(3C= 48 hrs)**

Course description: The main objective of this course is to give students an insight into the world of microorganisms. The paper discusses the historical developments and major milestones leading to the development of microbiology as a separate discipline of science. The students will understand the diversity, structure, evolution and impact of microbes in our day-to-day life and for the sustenance of life on Earth in general.

Learning Outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the significance of microbiology as a scientific discipline.	Understand
C.O. 2: Classify bacteria as per Bergy's manual	Understand
C.O. 3: Explain the diversity, distribution, cell structure, life cycles and economic importance of micro-organisms.	Understand
C.O. 4: Differentiate different microbes based on morphology using microscopy techniques.	Analyse
C.O. 5: Classify beneficial and non-beneficial microbes and their impact on society.	Understand
C.O. 6: Employ sterilization or decontamination procedures	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4					x	
C.O.5	x					
C.O.6		x				

MODULE I **(10 hrs)**

Microbiology History and scope of microbiology Bacteriology: Morphological classification, classification based on staining reaction, Ultrastructure of bacteria, Reproduction, Metabolism-Energetics, metabolic pathways, Economic importance, Mycoplasma and Actinomycetes-General account

MODULE II **(10 hrs)**

Virology: Virus-General characteristics, nomenclature, classification, structure, chemical composition, properties and reproduction of bacteriophages and TMV, Economic importance, Viral pathogens of plants and animals, Viroids and Prions, anti-viral vaccines, viral vectors, Coronavirus and Covid19 pandemic

MODULE III **(10 hrs)**

Plant-microbe Interaction: Adverse, mutualistic and commensal relationships between plants and microbes with examples, agricultural microbiology-Rhizosphere, the role of microbes in soil fertility, Nitrogen fixation, Biofertilizers, plant pathology; Classification of plant diseases based on causative organisms and symptoms-Host parasite interaction, phytoalexins, Leaf mosaic of Tapioca, citrus Canker, Blast disease of Paddy, Root wilt of coconut

MODULE IV **(10 hrs)**

Animal Microbe interaction: Adverse, mutualistic and commensal relationships between animals and microbes with examples, Cellular, Biochemical and genomic basis of microbial colonization, Infection and pathogenesis in animals, Zoonotic Diseases-Vectors, Fungal, bacterial and viral diseases, Overview on drugs and therapeutics, bacteriocide, antibiotics, antibiotic resistance, fungicide, mode of action

MODULE V **(8 hrs)**

Physical and chemical control of microbes. Principles of antimicrobial therapy: Various methods of control of microorganisms: physical, chemical and biological. Different methods of Sterilization-moist heat sterilization, Dry heat sterilization, Filter sterilization of thermolabile substances and air, chemical sterilization, Disinfection, and antisepsis, Antimicrobials, classification and modes of action. Antimicrobial resistance and their impact

REFERENCES

1. S.A.J. Tarr (1972). Principles of Plant Pathology. Macmillan International Higher Education.
2. T. V. R. Pillay [Ed.]. (1972). Coastal Aquaculture in the Indo Pacific Region, FAO.
3. T. V. R. Pillay and Dill W. A. [Eds.] (1979). Advances in aquaculture fishing. Fishing News Books.
4. Vita I.D. [Ed.] (1993). Freshwater pond culture and management. Scientific Publishers, Jodhpur.
5. Barg U.C(1997). Guidelines for the promotion of environmental management of coastal aquaculture development, DPH, Delhi.
6. Biswas K.P(1992). Prevention and control of fish and prawn diseases. NPH, Delhi.
7. Amlacher, F(1997). Textbook of Fish Diseases. NPH, Delhi.

8. Stephen Blaber. (1997). Fish and Fisheries of Tropical Estuaries. Chapman and Hall.
9. Rick Parker (2007). Aquaculture Science. Delmar-Thomson Learning.
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11. Bradley KM, Breyer JP, Melville DB, Broman KW, Knapik EW, Smith JR. 2011. An SNP- based linkage map for zebrafish reveals sex determination loci. G3 (Bethesda) 1:3-
12. Bradley KM, Elmore JB, Breyer JP, Yaspan BL, Jessen JR, Knapik EW, Smith JR. 2007. A major zebrafish polymorphism resource for genetic mapping.
13. Genome Biol 8(4): R55. Breder CM, Rosen DE, American Museum of Natural History. 1966. Modes of reproduction in fishes. Garden City (NY): Natural History Press. Darrow KO, Harris WA. 2004.
14. Characterization and development of courtship in zebrafish, Danio rerio. Zebrafish 1(1): 40-45. Devlin RH, Nagahama Y. 2002.
15. Sex determination and sex differentiation in fish: An overview of genetic, physiological, and environmental influences. Aquaculture 208:191-364.

BIO 10602- ANGIOSPERM (ANATOMY /PHYSIOLOGY/EMBRYOLOGY) (3C=48 hrs)

Course description: The aim is to acquaint the students with the internal basic structure and cellular composition of the plant body and correlate structure with important functions of different plant parts. The course focuses on the study of various tissue systems and their development and functions in plants. The course will also provide in-depth knowledge of the flowering and fruiting, reproduction process, the role of pollinators, ovule and seed development.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the anatomical features (cells and tissues, meristem, epidermal and vascular tissue systems) in plants.	Understand
C.O. 2: Explain various aspects of growth, reproduction, and development	Understand
C.O. 3: Differentiate Angiosperms based on anatomical features and classify accordingly.	Analyze
C.O. 4: Discuss the physiology of flowering and molecular and genetic aspects of reproduction.	Understand
C.O. 5: Differentiate monocot and dicot plants	Analyse
C.O. 6: Apply the knowledge on physiological aspects of plants to improve crop productivity in extreme weather conditions	Apply

MAPPING of CO's and PO's

Programme Outcomes

Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3					x	
C.O.4	x					
C.O.5					x	
C.O.6		x				

MODULE I **(10 hrs)**

Angiosperm Anatomy: Objective and scope of plant anatomy, Permanent tissues – Definition, classification - simple, complex and secretory, Tissue systems – Epidermal tissue systems-stomata, structure and functions, Ground tissue systems & vascular tissue systems. Different types of vascular arrangements, Apical meristems & theories on the apical organization - Apical cell theory, Histogen theory, Tunica -Corpus theory.

MODULE II **(8 hrs)**

Organization of root apex in dicots & monocots. Primary structure – Root, stem and leaf [Dicot & Monocot]. Secondary growth - Root and stem- cambium, periderm formation-phellem, phellogen and phelloderm, lenticels. Anomalous secondary growth, growth hormones.

MODULE III **(10 hrs)**

Physiology: General Introduction on physiological processes of higher plants, water relations of plants, Plasmolysis and its significance, Transpiration types and its Significance anti-transpirants, Guttation and its significance, Mineral nutrition, Translocation of solute, Pathway of movement, phloem transport, electro-osmotic theory. Photosynthesis, structure and function of the chloroplast, Two pigment systems; Mechanism of photosynthesis-Light reaction, Calvin cycle, C4 cycle and photorespiration,

MODULE IV (10 hrs)

Embryology Structure and development of anther, the structure of mature pollen and Male gametophyte. Structure and development of ovule. Female gametophyte Monosporic (Polygonum type) Fertilization – Double fertilization - Syngamy - triple fusion - post-fertilization changes. Endosperm types - nuclear, cellular - helobial - Ruminate endosperms, the function of endosperms.

MODULE V **(10 hrs)**

Development of the embryo in Dicot and Monocot. A brief account on Polyembryony, parthenocarpy**.** Asexual reproduction: Vegetative apomixis. Adventive embryony. Non-recurrent apomixis, diplospory, apospory, parthenogenesis, androgenesis, automixis, semigamy, agamic complex.

REFERENCES

1. Johri B. M, Srivastava P. S. 2015 Reproductive Biology of Plants Springer- Verlag Berlin and Heidelberg GmbH & Co.
2. Ramawat K.G. Mérillon J.M. and Shivanna K. R. 2014. Reproductive Biology of Plants. CRC Press.
3. Johri B. M. 2011. Embryology of Angiosperms. Springer.
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5. Pandey, S.N. & Chadha, A. 2000. Embryology. Vikas Publishing House Pvt. Ltd. New Delhi.
6. Pandey, A.K. 1997. Introduction to Embryology of Angiosperms. CBS Publishers and Distributors, New Delhi.
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8. Maheswari, P. 1980. Recent Advances in the Embryology of Angiosperms.

BIO 10603- EVOLUTION AND DEVELOPMENTAL BIOLOGY (3C= 48 hrs)

Course description: This course offers a chance to 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 of 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.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the relationship of the evolution of various	Understand

species and the environment they live in	
C.O. 2: Explain the molecular events associated with the developmental process of living forms from 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

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4				x		
C.O.5	x					

MODULE I (10 hrs)

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, The "C-Value paradox",

MODULE II (10 hrs)

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, Evolution of human brain-communication, speech and language. Evolution of culture.

MODULE III **(10 hrs)**

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, blastocyst.

MODULE IV **(10 hrs)**

Cell differentiation: totipotency, pleuripotency 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 **(8 hrs)**

Human - implantation, pregnancy, parturition. Placentation in mammals - different types of 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

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14. Venna, P.S. and V.K. Agarwal (2007). Chordate Embryology. S. Chand & Co. Ltd.
15. Vijayakumaran Nair, K. and P.V. George (2002).A manual of Developmental Biology. Academica, Trivandrum.
16. Werner. A. Muller. (2008). Developmental Biology. Springer.

BIO 10604 PARASITOLOGY AND IMMUNOLOGY (3C= 48 hrs)

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 life cycles of parasites; has helped in defying the stigmas and religious taboos for many societies making free many of the people from superstition and ill-health. The course shall surely skill the students to see, appreciate and understand the diversities 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.

Learning Outcomes:

Course Outcome After the completion of the course, the student will be able to	**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 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	Analyze
C.O.5:Differentiate various parasites as per morphology	Analyze
C.O.6:Evaluate various blood cells and immune cells based on markers	Evaluate

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4					x	
C.O.5					x	
C.O.6						x

MODULE I **(8 hrs)**

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 **(10 hrs)**

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 **(10 hrs)**

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 **(10 hrs)**

Introduction, history, development and scope, Immunity: definition, classification of immunity. Innate and adaptive, Components of 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 **(10 hrs)**

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.

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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[Latest edition].
7. Fundamentals of Immunology by William E. Paul, Lippincott Williams & Wilkins Publishing [Latest edition].
8. Cellular and Molecular Immunology by Abul K. Abbas, Andrew H. Lichtman, Shiv Pillai, Elsevier Publishing [Latest edition].

BIO 10605- PLANT LAB 2 **(2C= 32 hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Apply various culture techniques for the identification of microbes	Apply
C.O. 2: Analyze the various bacteria using gram staining method	Analyze
C.O.3: Identify different anatomical features of angiosperms viz., meristems, roots, leaf, anther and pollen	Remember

C.O. 4: Identify various stages of embryo development in angiosperms	Remember
C.O. 5: Compare various plant tissue culture media and their composition for the development of regeneration protocols	Analyze/Create
C.O. 6: Differentiate various explants and their response in various media composition	Analyze
C.O.7:Design protocols for micropropagation and prepare synthetic seeds of important plants	Create

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1		x				
C.O.2					x	
C.O.3				x		
C.O.4				x		
C.O.5					x	
C.O.6					x	
C.O.7			x			

Microbiology

1. Sterilization technique-chemical, UV and autoclaving.
2. Culture techniques-spread plate/streak plate/ single colony/ stab culture
3. Antibiotic sensitivity assay
4. Cryo-stock preparation-glycerol stock
5. Test for the Coliform bacteria in contaminated water
6. Isolation of Rhizobium from root nodules of leguminous plants.
7. Examination of different types of bacteria
8. Gram staining

Angiosperm (Anatomy /Physiology/Embryology)

1. Study of meristems through permanent slides and photographs.
2. Simple permanent tissue – Parenchyma, Chlorenchyma, Aerenchyma, Collenchyma and Sclerenchyma.
3. Primary structure – Dicot stem: Hydrocotyle, Monocot stem: Grass
4. Dicot root: Limnanthemum, Monocot root: Colocasia or any monocot root.
5. Secondary structure – Stem [Normal type]- Vernonia, Secondary structure – Root [Normal

type] Ficus or Carica papaya.

6. Anomalous secondary thickening – Boerhaavia
7. Leaf: Epidermal structures –Stomata. Dicot and Monocot leaf (only Permanent slides).
8. Adaptive anatomy: Xerophyte (Nerium leaf); Hydrophyte (Hydrilla stem).
9. Structure of anther (young and mature), tapetum (amoeboid and secretory) (Permanent slides).
10. Female gametophyte: Polygonum (monosporic) type of Embryo sac Development (Permanentslides/photographs).
11. Pollen germination: in vitro and in vivo viability tests.
12. Study of pollen types using acetolysed and non-acetolysed pollen.
13. Ultrastructure of mature egg apparatus cells through electron micrographs
14. Determination of osmotic potential of plant cell sap by the plasmolytic method.
15. To study the effect of two environmental factors (light and wind) on transpiration by excised twig.
16. Calculation of stomatal index and stomatal frequency of a mesophyte and a xerophyte.

Plant tissue culture

1. Fundamentals and Techniques of Plant Tissue Culture
2. Sterilization methods: physical and chemical
3. Preparation of various tissue culture media: MS and Rooting media
4. Explant preparation, inoculation and initiation of tissue culture
5. Callus formation, Multiplication and Organogenesis
6. Establishment of suspension cultures
7. Micropropagation – Meristem and Nodal culture
8. Preparation of synthetic seeds
9. Protoplast isolation and Culture
10. Hardening and acclimatization in greenhouse

BIO 10606- ANIMAL LAB 2 **(2C= 32 hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	Cognitive Level
C.O. 1: Identify and Analyze different fossils and differentiate between analogous and homologous structures	Analyze
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 Analyze
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
C.O. 6: Assess the food quality and evaluate various adulterant in fro different types of food	Evaluate
C.O. 7: Identify various storage pests and assess their control options	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1					x	
C.O.2					x	
C.O.3				x	x	
C.O.4					x	
C.O.5		x				
C.O.6						x
C.O.7	x					

<u>Evolution And Developmental Biology</u>

1. Study of fossils from models/pictures.
2. Study of homology and analogy from suitable specimens.
3. Construction of cladograms based on morphological characters.
4. Study of whole mounts and sections of developmental stages of frog through permanent slides: Cleavage stages, blastula, gastrula, neurula, tail-bud stage, tadpole (external and internal gill stages)

5. Study of whole mounts of developmental stages of a chick through permanent slides (Hamburger and Hamilton Stages): Stage 3 (Intermediate Streak)-13 hours, Stage 4 (Definitive Streak)-18 hours, Stage 5 (Head Process)-21 hours, Stage 7-24 hours, Stage 8-28 hours, Stage10- 33 hours, Stage 11- 40 hours , Stage 13-48 hours, Stage 19- 72 hours and Stage 24-96 hours of incubation
6. Demonstration of the culture of chick embryos from fertilized eggs to study various developmental stages.
7. Study of different sections of the placenta (photomicrographs/ slides).
8. Project report on Drosophila culture/chick embryo development.
9. A visit to Poultry Farm/IVF Centre

Parasitology and Immunology

1. Study of life stages of Entamoeba histolytica, Giardia intestinalis, Trypanosoma 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.
4. Study of Pediculus humanus (Head louse and Body louse), Xenopsylla cheopis and Cimex lectularius through permanent slides/ photographs.
5. Demonstration of lymphoid organs.
6. Histological study of the spleen, thymus and lymph nodes through slides/photographs.
7. Preparation of stained blood film to study various types of blood cells.
8. Basic patterns of precipitation by Ouchterlony's double immuno-diffusion method.
9. ABO Blood group antigen determination by haemagglutination.
10. Cell counting and viability test from splenocytes of farm-bred animals/cell lines.
11. Demonstration of: (a) ELISA (b) Immunoelectrophoresis
12. Detection of complement activity using haemolysis of antibody-coated SRBC and standard serum

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Food, Nutrition and Health

1. To detect adulteration in a) Ghee b) Sugars c) Tea leaves and d) Turmeric

2. Estimation of Lactose in milk and diagnosis of lactose intolerance by measuring hydrogen as during expiration.
3. Ascorbic acid estimation in food by titrimetry
4. Estimation of Calcium in foods by titrimetry
5. Study of the stored grain pests from slides/photographs (Sitophilus oryzae, Trogoderma granarium, Callosobruchus chinensis and Tribolium castaneum): their identification, habitat and food sources, damage caused and control. Preparation of temporary mounts of the above- stored grain pests.
6. Visit food testing lab /or any agency of food standards
7. Undertake computer-aided diet analysis and nutrition counseling for different age groups.
8. Identify nutrient-rich sources of foods (fruits and vegetables), their seasonal availability and price.
9. Study of nutrition labeling on selected foods

BIO 10607- OPEN END LAB II (2C= 32 hrs)

BIO10608- FOOD, NUTRITION AND HEALTH (2C=32 hrs)

Course description: The prime focus is to provide the students with a basic understanding of the relationship between food, nutrition and health. It is imperative that focus should be on realistic issues faced by people with respect to nourishment at all stages of life. Unhealthy eating habits particularly the shift from fresh food consumption to packaged foods with added salts and preservatives have contributed to the obesity epidemic in nearly all parts of the world. It is important to understand this link and change eating habits in accordance to one`s age, pregnancy, lactation and physical activity. By taking steps to eat healthy, one can obtain the nutrients required by the body to stay healthy, active, and strong. Apart from physical activity, the intake of the required vitamins, minerals and antioxidants also nourishes the brain. Malnutrition is the main cause of impairment of growth in young children and infants and leads to diseases like Marasmus. Moreover, food hygiene including food and water-borne infections along with food spoilage has also been covered in this course.

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	Cognitive Level
C.O.1. Explain the association of food and nutrition in promoting healthy living.	Understand
C.O.2. Describe the holistic relationship between nutrition science and health.	Understand
C.O.3. List the nutrition associated disorders or diseases	Remember
C.O. 4. Discuss how neutraceuticals could serve as medicines	Understand
C.O.5. Explain the importance of nutraceutical science and its application for human welfare	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3				x		
C.O.4	x					
C.O.5	x					

MODULE I **(6 hrs)**

Basic concept of food and nutrition: Food Components and food-nutrients, Concept of a balanced diet, nutrient needs and dietary pattern for various groups- adults, pregnant and nursing mothers, infants, school children, adolescents and elderly. Food Pyramid, Nutritional anthropometry- BMI, waist-to-hip ratio, skin-fold test and bioelectrical impedance; interpretation of these measurements.

MODULE II **(6 hrs)**

Nutritional Biochemistry: Carbohydrates, Lipids, Proteins, their dietary source and role Vitamins- their dietary source and importance Minerals- their biological functions. Dietary Fibres - Definition, their dietary source and nutritional importance. Elementary idea of Probiotics, Prebiotics, Organic Food.

MODULE III **(8 hrs)**

Health: Definition and concept of health, Major nutritional Deficiency diseases- (kwashiorkor and marasmus), Deficiency disorders, their causes, symptoms, treatment, prevention and government programmes, if any. Lifestyle-related diseases- hypertension, diabetes mellitus, Atherosclerosis and obesity- their causes and prevention through dietary and lifestyle modifications, Social health problems- smoking, alcoholism, drug dependence and Common ailments- cold, cough, and fevers, their causes and treatment.

MODULE IV (6 hrs)

Food hygiene: Food and Waterborne infections; Bacterial infection: Cholera, typhoid fever, dysentery; Viral infection: Hepatitis, Poliomyelitis; Protozoan infection: amoebiasis, giardiasis; Parasitic infection: taeniasis and ascariasis their transmission, causative agent, sources of infection, symptoms and prevention; Brief account of food spoilage: Causes of food spoilage and their preventive measures.

MODULE V (6 hrs)

Nutraceuticals and Functional foods: Introduction to Nutraceuticals as Science, Properties, structure and functions of various Nutraceuticals: Glucosamine, Octacosanol, Lycopene, Carnitine, Melatonin and Ornithine alpha-ketoglutarate. Use of proanthocyanidins, grape products, flaxseed oil as Nutraceuticals. Nutraceuticals bridging the gap between food and drug, Nutraceuticals in treatment for various disorders. A brief idea about some Nutraceutical rich supplements e.g. Bee pollen, Caffeine, Green tea, Lecithin, etc. Types of inhibitors present in various foods and how they can be inactivated. General idea about the role of Probiotics and Prebiotics as nutraceuticals.

REFERENCES

1. Shashi Goyal & Pooja Gupta. Food, Nutrition and Health (ISBN: 9788121940924)
2. Linda Tapsell. Food, Nutrition and Health. I Edition, Oxford (ISBN: 978-0195518344)
3. Gibney MJ et al. (eds) (2009) Introduction to Human Nutrition. Wiley-Blackwell A John Wiley & Sons Ltd, Nutritional Society.
4. Mann J and Truswell SA, Essentials of Human Nutrition, Oxford University Press
5. Yuan Kun Lee and Seppo Salminen: Handbook of Probiotics and Prebiotics, second ed., John Wiley & Sons, Inc.
6. James Robinson, Deborah J McCornick, Concepts in Health and Wellness, Delmar Cengage Learning, 1st ed
7. Jeremy Hawker, Norman Begg, Iain Blair, Ralf Reintjes, Julius Weinberg, Communicable Disease Control Handbook, 2nd ed
8. Clive de W Blackburn, Food Spoilage Microorganisms, Woodhead Publishing Limited, Cambridge

BIO 10609- PLANT TISSUE CULTURE (2C= 32 hrs)

Course description: This course explores the use of biotechnology to both generate genetic variation in plants and to understand how factors at the cellular level contribute to the expression of genotypes and hence to phenotypic variation.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the basic concepts, principles and processes in plant tissue culture	Understand
C.O. 2: List plant hormones, characteristics and their function	Remember
C.O. 3: Employ tissue culture techniques for R&D and for crop improvement and productivity purposes.	Apply
C.O. 4: Discuss the mechanism of agrobacterium mediated gene transfer for plant improvement.	Understand
C.O. 5: Explain the defense mechanisms in plants and the significance of secondary metabolites.	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2			x			
C.O.3		x				
C.O.4	x					
C.O.5	x					

MODULE I **(6 hrs)**

History and Fundamentals of plant tissue culture, laboratory design and sterilization techniques, tissue culture media and preparation, concepts of tissue culture, initiation of plant tissue culture, techniques in plant tissue culture, explant preparation and inoculation, callus formation, multiplication and organogenesis, the establishment of suspension cultures, micropropagation, protoplast culture and fusion, and somatic embryogenesis, the culture of reproductive structures, synthetic seed technology, somaclonal variation.

MODULE II **(6 hrs)**

Plant Growth Hormones and their role in plant tissue culture: discovery, structure, mode of action of the major plant hormones, Plant cell differentiation (Pluripotency and Totipotency).

MODULE III **(7 hrs)**

Application of tissue culture for crop improvement in agriculture, horticulture and forestry, Seed storage proteins, Methods for Plant Conservation, Haploid production, Anther, Pollen, Embryo and ovule culture and their applications, Plant genome organization, Organization and expression of chloroplast genome and mitochondrial genome, Cytoplasmic male sterility., Intergenomic interaction

MODULE IV **(7 hrs)**

Secondary metabolite: Role of Secondary Metabolites in Defense, Communication in insets, plants, animals, Chemical Ecology, Interaction between organism using secondary metabolites. Production of bioactive secondary metabolites by plant tissue culture. Applications of secondary metabolites: Isolation and characterization – drug development, Biopesticides, growth regulators, Biofertilizers. Value addition via biotransformation. Biocatalyst, Bioremediation, Biofuels, Feedstock Chemicals, Designer Chemicals.

MODULE V **(6 hrs)**

Agrobacterium and crown gall tumors: - Ti plasmid & Ri Plasmid vectors. Mechanism of T-DNA transfer to plants, Agro infection. Plant viral vectors. Direct transformation of plants by physical methods. Genetic engineering in plants: -Selectable markers, Reporter genes and Promoters used in plant vectors., Genetic engineering of plants for the production of antibodies, viral antigens and peptide hormones in plants, biodegradable plastics in plants.

REFERENCES

1. An introduction to Plant Tissue culture by MK Razdan. M.K. 2003. Oxford & IBH Publishing ohn Wiley & Sons, 2002.
2. Molecular Biotechnology by Glick, B.R. and J.J. Pasternak. Second Edition, ASM Press, Washington, 1998.
3. Plant tissue culture by Bhojwani. S.S and Razdan. M.K 2004.
4. Plant Propagation by Tissue Culture: Volume 1 & 2. EF George. Exegetics Limited, 1999.
5. Plant cell culture, A Practical Approach, 2nd Edition, Edited by R.A. Dixon and R.A. Gonzales.
6. Natural Products: A Laboratory Guide By Raphael Ikan. Academic Press,1991.
7. Chemistry of Natural Products by Sujata V. Bhat, Bhimsen A. Nagasampagi, Meenakshi Sivakumar. Birkhäuser, 2005.
8. Phytochemical Methods A Guide to Modern Techniques of Plant Analysis By JB Harborne. Springer, 1998.

SEMESTER VII

BIO10701- CELLULAR METABOLISM (3C= 48 hrs)

Course Description: This advanced course in biochemistry includes the study of bioenergetics and the metabolism of carbohydrates, amino acids, fatty acids, nucleic acids as well as Electron transport chains. Besides, understanding the regulation of metabolism and the inborn errors of metabolism are also included.

Learning Outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the thermodynamic principles governing biochemical changes.	Understand
C.O. 2: Calculate free energy change, redox potential to assess the thermodynamic feasibility of biological processes	Analyze
C.O. 3: Assess the energetics of catabolic degradation of intermediates in various metabolic pathways.	Evaluate
C.O. 4: Describe the fundamentals of metabolism of carbohydrate, fatty acid amino acid and nucleic acid and their regulation and inborn errors leading to clinical manifestations.	Understand
C.O. 5: Identify and calculate the quantity of biomolecules (carbohydrate, fatty acid amino acid and nucleic acid).	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2				x		
C.O.3						x
C.O.4	x					
C.O.5					x	

MODULE I (10 hrs)

Bonds and interactions in Biology; Bioenergetics, High energy compounds, ATP, Oxidation-reduction potential. Carbohydrate Chemistry & metabolism: Overview of Carbohydrate chemistry, biosynthesis, catabolism and their regulation; Glycolysis, Gluconeogenesis, Glycogenesis, Glycogenolysis, Pentose phosphate pathway, Citric acid cycle, Glyoxalate cycle, Overview on glycoconjugates structure and function, Disorders of Carbohydrate metabolism.

MODULE II **(10 hrs)**

Lipid Chemistry & metabolism: Overview on types and functions of lipids. Biosynthesis, catabolism of fatty acids and their regulation; alpha, beta and omega oxidation with emphasis on Beta oxidation, the significance of Ketone bodies and their metabolism. Biosynthesis of different lipids; phospholipids, glycolipids, Cholesterol, Eicosanoids; Inborn errors of lipid metabolism.

MODULE III **(10 hrs)**

Amino acid Chemistry & metabolism: Overview of amino acids and protein, Protein degradation in cells, Amino acid deamination, Urea cycle, metabolic breakdown of individual amino acids, Amino acids biosynthetic precursors and biosynthesis (essential and nonessential amino acids), Nitrogen fixation, inborn errors of amino acid metabolism.

MODULE IV **(10 hrs)**

Nucleic acid Chemistry & metabolism: Overview of nucleic acids and the bases, Biosynthesis (*denovo* and salvage pathways) & catabolism of purines and pyrimidines. Regulation of nucleic acid metabolism; disorders of nucleic acid metabolism, Inhibitors of nucleotide biosynthesis as chemotherapeutic agents.

MODULE V **(10 hrs)**

Photosynthesis and Electron Transport Chain: Biochemical aspects of Reaction centers, Quantum yield. Oxidative phosphorylation: Oxidative phosphorylation–chemiosmotic model, ATP synthase (F_0F_1complex), proton gradient, rotational catalysis, shuttle systems to move reducing equivalents from cytosol to mitochondrial matrix; Regulation of oxidative phosphorylation.

REFERENCES

1. Voet, D. & Voet J. G. Biochemistry (2012). 4th edition, John Wiley and Sons
2. Stryer, Lubertet al., (2015). Biochemistry.8thedition.W.H. Freeman and Co.
3. Lehninger, A. L., Nelson, David L., Cox, Michael M. (2013). Principles of Biochemistry. 6th revised edition. Freeman and Co.
4. Devlin, Thomas. M. (2010). Textbook of Biochemistry with Clinical Correlations- 7th edition. John Wiley & Sons.
5. Robert, K., Granner, D. K., & Mayes, P. A. M. (2003). Harper's illustrated biochemistry.
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12. Mu, P., & Plummer, D. T. (1988). Introduction to practical biochemistry. Tata McGraw-Hill Education.
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BIO10702- CELL BIOLOGY (3C= 48 hrs)

Course Description: This course will focus on understanding the structure and function of the cell, which is fundamental to all of the biological sciences. The advanced course in cell biology will focus on both Prokaryotic and Eukaryotic cell biology. The course will help to develop insight into the complexities of cell structure and function and the molecular events that mediate cellular processes, with a specific focus on membrane structure and composition, transport and trafficking; the cytoskeleton and cell movement; and the integration of cells into tissues. In addition, the course will also cover important cellular processes such as cell cycle regulation, signal transduction, metabolic processes, and apoptosis and will attempt to relate defects in these various cellular processes to human diseases.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the fundamentals of cell signaling	Understand
C.O. 2: Describe the structure and function of biological membranes, and analyze cell-cell and cell-matrix interactions and intracellular transport of proteins.	Understand
C.O. 3: Differentiate cellular organelles with the aid of microscopic imaging	Analyze
C.O. 4: Describe how cells grow, divide and die, and how these important processes are regulated.	Understand
C.O. 5: Differentiate different stages in cell cycle based on DNA content	Analyze
C.O.6: Differentiate healthy and dying cells based on morphology, biochemical and molecular basis	Analyze
C.O.7: Analyse a given theoretical problem/case, identify gaps in knowledge and retrieve knowledge independently to be able to present a scientifically sound solution	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2	x					
C.O.3					x	
C.O.4	x					
C.O.5					x	
C.O.6					x	
C.O.7		x				

MODULE I (10 hrs)

The Dynamic Architecture and Composition of Cells, Structure and functions of cellular constituents, Membranes and cell architecture, Membrane trafficking, Ion channels and electrical properties of membranes, Transport of ions & small molecules, Protein transport into membranes and organelles, Vesicle trafficking; Vesicle Formation & Cargo Sorting, Vesicle Targeting and Fusion,

MODULE II (10 hrs)

Cells in Their Social Context, Microenvironment of the Cell, Cell communication, Cell polarity, Cytoskeleton-Microfilaments, Microtubules, intermediate Filaments, Actin Dynamics, Membrane Channels, receptor mechanisms of action, Cell-Cell Interaction, Cell-Matrix Interactions, Cell Migration and its Control Mechanisms.

MODULE II (10 hrs)

Cell Signaling and Signal Transduction: Ligands and surface receptors, GTP binding proteins, cAMP and Calcium signaling, Receptors and associated kinases, RTK signaling and other mechanisms, Major cell-cell signaling pathways—Wnt, TGFβ, Hedgehog (Hh), receptor tyrosine kinase (RTK), nuclear receptor, Jak/STAT, and Notch, Relationships between Signaling Pathways

MODULE IV (10 hrs)

Cell cycle, checkpoints, and regulation, Mechanisms of Cell Growth, Survival, Cellular senescence, cell death, Autophagy, Mitophagy, Lysosome-dependent cell death, Apoptosis, necroptosis, Ferroptosis, Pyroptosis, Cellular senescence, cell cycle defects and pathogenesis.

MODULE V **(8 hrs)**

Techniques in cell biology: Advanced Microscopic and flow cytometry techniques, FRET-based assessment of cell signaling, Immune cell sorting and analysis, FISH, Karyotyping, pathological examinations, Western blotting, Determination of calcium flux, localization and translocation of proteins during various cellular events, tracking of cellular events like apoptosis and autophagy, etc, 3D culturing of cells, insect, plant and animal cell isolation and culturing techniques.

REFERENCES

1. Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts, and Peter Walter, Molecular Biology of the Cell (6th Edition) by Garland Science; 2014
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
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BIO 10703- ENZYMOLOGY **(3C= 48 hrs)**

Course Description: This course on enzymology covers the classification, naming, isolation and purification of enzymes. It also includes the structure and general properties of enzymes, mechanisms of enzyme catalysis, Enzyme kinetics, different types of enzyme inhibition, regulation of enzymes and applications of enzymes.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain principles underlying classification & nomenclature of enzymes and employ suitable methods for isolation and of purification enzymes from different sources.	Understand
C.O. 2: Compare the structure, general properties of enzymes to their mechanism of action.	Analyze
C.O. 3: Analyse the enzyme kinetics to study enzyme characteristics and analyze kinetic parameters to differentiate different types of enzyme inhibition.	Analysis
C.O. 4: Explain and evaluate the role of regulatory enzymes in the regulation of metabolic pathways.	Understand
C.O. 5: Discuss the applications of enzymes in medicine, industry and genetic engineering and also to design synthetic enzymes.	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4	x					
C.O.5	x					

MODULE I **(10 hrs)**

Enzyme nomenclature and classification, the six main classes of enzymes and their subclasses. Extraction and Purification of Enzymes: Extraction of soluble and membrane-bound enzymes; Purification of enzymes; Criteria of enzyme purity; Assay of enzymes; Zymography.

MODULE II **(10 hrs)**

Structure and General properties of enzymes; Enzyme substrate complex; Reaction coordination diagram; Lowering of activation energy; Specificity of enzyme- lock and key hypothesis, induced fit hypothesis and strain or transition state stabilization hypothesis; Mechanism of enzyme catalysis: Acid-base catalysis, covalent catalysis and metal ion catalysis; Factors affecting enzyme activity; Isozymes; Coenzymes; Metalloenzymes; Membrane-bound enzymes; Multienzyme complexes

MODULE III **(10 hrs)**

Kinetics of enzyme catalysed reactions: The relationship between initial velocity and substrate concentration - Michaelis-Menton, Lineweaver–Burk, Eadie-Hofstee and Hanes-Woolf equations and their applications; Pre-steady state kinetics, Fast kinetics to elucidate the intermediates and rate-limiting steps; Enzyme inhibitors.

MODULE IV **(10 hrs)**

Regulatory enzymes and metabolic regulations: Allosteric enzymes, Hill equation. Important metabolic pathways regulated by allosteric enzymes; Regulation of enzymes by covalent modification and zymogen activation. Investigations of active site structure: methods of active site mapping.

MODULE V **(8 hrs)**

Applications of Enzymes: in medicine-diagnostic, in therapeutics, as reagents in clinical chemistry, Enzymes and inborn errors, Industrial applications of enzymes; Applications in genetic engineering/ gene editing. Synthetic Enzyme: Ribozymes, Catalytic antibodies, Enzyme engineering (Protein engineering). Enzyme Immobilization; Immobilization of enzymes and their applications, Kinetics of immobilized enzymes. Biosensors.

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3. Uhlig, H. (2015). Industrial enzymes and their applications. John Wiley & Sons.
4. Palmer, T., & Bonner, P. L. (2007). Enzymes: biochemistry, biotechnology, clinical chemistry. Elsevier.
5. Chaplin, M.F., Burke, C. (1990). Enzyme technology. Cambridge University Press.
6. Grundwald, D. Peter. (2016). Biocatalysis: Biochemical Fundamental and Applications.2nd reprint Edition.
Imperial College Press
7. Grunwald, P. (2009). Biocatalysis: biochemical fundamentals and applications. Imperial College Press.

BIO 10704- MOLECULAR BIOLOGY (3C= 48 hrs)

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.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**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 hypothesis	Analyse
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

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4					x	
C.O.5					x	

MODULE I (10 hrs)

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 (Hemoglobin, Myoglobin).

MODULE II (8 hrs)

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 (10 hrs)

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 (10 hrs)

Promoter analysis and characterization: Deletion mapping, Transient/stable expression system, S1/RNase mapping, EMSA, DNase I Footprinting. 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 **(10 hrs)**

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

BIO 10705- BIOCHEMISTRY LAB **(2C= 32hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Evaluate and estimate various biomolecules using standard biochemical techniques	Evaluate
C.O. 2: Analyze the effect of physiological factors such as temperature and pH o the protein folding and structure	Analyse
C.O. 3: Identity carbohydrate (sugars), amino acids/protein, cholesterol and triglycerides and nucleic acids	Remember and Analyze
C.O. 4: Assess the enzyme properties extracted from plant/animals/microbes	Evaluate
C.O. 5: Apply chromatographic and electrophoretic techniques for purification and molecular analysis of the proteins	Apply
C.O. 6: Evaluate the enzyme activity and optimum temperature and pH of the enzymes	Evaluate
C.O. 7: Analyze the importance of enzyme inhibitors in biochemical pathways	Analyze

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1						x
C.O.2					x	
C.O.3				x	x	
C.O.4						x
C.O.5		x				
C.O.6.						x
C.O.7.					x	

Cellular metabolism

1. Preparation and assessment of the quality of buffers.
2. Estimation of protein concentration by plotting a standard graph of BSA using a UV spectrophotometer.
3. Estimation of total carbohydrates and free amino acids in cereals.
4. Estimation of protein molecular weight using standard markers and SDS- Polyacrylamide Gel Electrophoresis.
5. Gel Filtration Chromatography.
6. Affinity purification of a recombinant protein and assessment of purity.
7. Identification of proteins using immunoblotting.
8. Determination of the catalytic efficiency of a standard enzyme.
9. A binding assay to quantitate interaction between biological macromolecules.
10. Identification of carbohydrate (sugars), amino acids/protein, cholesterol and triglycerides and nucleic acids
11. Estimation of serum SGOT and SGPT, creatine kinase levels
12. Fluorescence spectroscopy to study the effect of temperature and pH on protein structure.
13. Determination of catalase and cytochrome oxidase enzyme activity of various bacterial strains
14. Other biochemical like citrate utilization, indole, Conversion of lactose to acid, etc using bacterial strains

Enzymology

1. Extraction of an enzyme from an animal/plant/microbial source.
2. Ammonium sulfate/Acetone precipitation of the extracted enzyme.
3. Purification of the enzyme by a suitable chromatographic technique.
4. Determination of molecular weight of the enzyme by SDS PAGE.
5. Progress curve for the enzyme-catalyzed reaction.
6. Assay of the enzyme to determine activity and specific activity
7. Effect of [S] on velocity: Michaelis-Menton Plot and Lineweaver-Burk plot- determination of Km and Vmax.
8. Determination of optimum pH and temperature of the enzyme.
9. Effect of inhibitors on enzyme activity.

BIO 10706- CELL AND MOLECULAR BIOLOGY LAB (2C= 32 hrs)

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Define various cell culture methods and their maintenance	Remember
C.O. 2: Analyze various organelles of cells using imaging	Analyse
C.O. 3: Identify various stages of cell cycle using FACS	Remember and Analyze
C.O. 4: Apply the techniques of tissue sectioning and fixation for studying histology	Apply
C.O. 5: Assess the classical Mendelian ratios using Chi-square analysis	Evaluate
C.O. 6: Evalute the enzyme activity and optimum temperature and pH of the enzymes	Evaluate
C.O. 7: Apply Pedigree analysis to study the inheritance of various genetic disorders	Apply
C.O.8: Analyze the nucleic acid using PCR based amplification and blotting techniques	Analyze
C.O.9: Employ molecular biology techniques (restriction digestion and cloning) for nucleic acids	Apply

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1				x		
C.O.2					x	
C.O.3				x	x	
C.O.4		x				
C.O.5						x
C.O.6.						x
C.O.7.		x				
C.O.8.					x	
C.O.9.		x				

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. Histology
8. Tissue fixation
9. Tissue sectioning using a cryostat
10. Visualization of the processed tissue samples
11. Immunocytochemistry

Genetics and Molecular Biology

1. Verification of Mendelian ratios using Chi-square analysis/test.
2. Linkage maps based on data from conjugation.
3. Linkage maps based on data from Drosophila crosses.
4. Pedigree analysis- sex-linked disorders, autosomal disorders
5. Study of human karyotype (normal and abnormal)

6. DNA and RNA isolation
7. Primer designing
8. PCR and semi-quantitative RT PCR
9. Analysis of PCR products on an agarose gel.
10. Southern/Northern/Western hybridization techniques
11. Restriction digestion and analysis
12. Competent cell preparation and analysis of efficiency

BIO 10707- GENETICS **(2E= 32 hrs)**

Course description: Genetics is offered as a core course that provides fundamental knowledge of how organisms, populations and species evolve. Apart from Mendel's laws and basic genetics, at the Master's level, this course will provide some of the most incisive analytical approaches that are now being used across the spectrum of biological disciplines.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1: Describe fundamental molecular principles of genetics	Understand
C.O.2: Interpret genetic mapping and analyze crossing data	Analyze
C.O.3: Analyze pedigree charts to come up with predicting genotype and probability of occurrence of particular genotype and phenotype	Analyze
C.O. 4: Explain the inheritance of complex traits	Understand
C.O.5: Analyze banding pattern and its use for analyzing the genetic basis of cancer	Analyze

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4	x					
C.O.5					x	

MODULE I **(5 hrs)**

Mendel's laws and their chromosomal basis; extension of Mendel's principles: allelic variation and gene function- incomplete dominance and co-dominance, allelic series, testing gene mutations for allelism; gene action- from genotype to phenotype–penetrance and expressivity, gene interaction, epistasis, pleiotropy. Evolution of the concept of the gene, fine structure of a gene (rII locus)

MODULE II **(6 hrs)**

Linkage, Crossing Over and Chromosome Mapping in Eukaryotes: Methods of gene mapping: 3-point test cross in Drosophila, Pedigree analysis of Monogenic traits - Autosomal inheritance-dominant, recessive Sex-linked inheritance, Sex-limited and sex-influenced traits, Mitochondrial inheritance, OMIM number, Human genome and mapping.

MODULE III **(6 hrs)**

Complications to the basic pedigree patterns- non-penetrance, variable, expressivity, pleiotropy, late-onset, dominance problems, anticipation, genetic heterogeneity, genomic imprinting and uniparental disomy, spontaneous mutations, mosaicism and chimerism, male lethality, X-inactivation; LOD score for linkage testing, genetic disorders, methods for detection of induced mutations; P- element insertional mutagenesis in Drosophila; DNA damage, repair and recombination.

MODULE IV: **(7 hrs)**

Genomes and Genomics, functional genomics and reverse genetics; Complex traits, measuring and analyzing quantitative variation, narrow sense and broad-sense heritability, QTLs and mapping QTLs, Human quantitative traits, Haplotype mapping and GWAS The epigenome, including epigene modifications, such as DNA methylation, histone modification, chromatin remodeling and non-coding RNAs; cellular maintenance of the epigenome; epigenetic control of gene expression, and epigenetics and development. X inactivation and genomic imprinting.

MODULE V **(8 hrs)**

Human genetics- Chromosome banding, karyotype and nomenclature of metaphase chromosome; chromosomal anomalies in malignancy (chronic myeloid leukemia, Burkitt's lymphoma, retinoblastoma and Wilms' tumor); oncogenes and tumor suppressor genes- genetic pathways to cancer.

REFERENCES

1. Introduction to Genetic Analysis, Griffith, AJF, Wessler SR, Carol SB and Dobley J., 11th edition, 2015, W.H. Freeman and Co.
2. Genetics: From Genes to Genomes, Hartwell LH, Goldberg ML, Fischer JA and Hood L., 6th edition, 2018, McGraw Hill.
3. Principles of Genetics, E.J. Gardner and D.P. Snustad, 7th edn, 2015, John Wiley and Sons
4. Genetics, Monroe W. Strickberger 3rd revised edition, 2008, Prentice Hall Pvt. Ltd
5. Essential Genetics- A Genomic Perspective- Daniel L.H, 4th edition, 2005, Jones and Bartlett, USA
6. Principles of Genetics, Robert H. Tamarin, 7th edition, 2007, Tata McGraw-Hill
7. Genetics: a Conceptual Approach, Pierce, B. A., 6th edition, 2016 W.H. Freeman.
8. Evolutionary Genetics, Smith, J. M. 1999, 2nd edition, Oxford University Press.
9. Genetics: Analysis of Genes and Genomics, Hartle, L, 8th edition, 2011, Jones and Barlett, USA
10. Emery's Elements of Medical Genetics, Turnpenny P, and Ellard S, 15th edition, 2017, Elsevier
11. Molecular and Genetic Analysis of Human Traits, Maroni, 2001, Wiley-Blackwell
12. Approaches to Gene Mapping in Complex Human Diseases, Haines and Pericak, 2006, Wiley
13. Selected research papers to be given

BIO 10708- BREEDING AND CULTURE TECHNIQUES **(2E= 32 hrs)**

Course techniques: The course will focus on the commercially important plants, their breeding systems and strategies employed for crop improvement. The paper also covers the aspects of horticulture. Animal breeding and aquaculture are the other important techniques covered under this course.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	Cognitive Level
C.O.1: Learn various plant breeding techniques and familiarize with centers for germplasm preservation.	Understand
C.O.2: Appreciate the presence of polyploidy in nature and its application in breeding	Understand
C.O.3: : Describe the importance and use of animal breeding and its industrial application.	Understand
C.O. 4: Design aquaculture set up for fish breeding and use it as a start-up	Create

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4						x
C.O.5						

MODULE I **(7 hrs)**

Plant Breeding: Definition, Objectives. Importance of floral biology in plant breeding, Methods of crop improvement, Sources of germplasm. Centers of genetic diversity, Genetic erosion, Preservation and utilization of germplasm. Gene banks. plant introduction agencies in India- rules and regulations, NBPGR. International exchange of germplasm, Mass selection, pure line selection, clonal selection, Hybridization. Role of interspecific and intergeneric hybridization in crop improvement, Genetics of incompatibility and sterility, Role in crop improvement, Types of male sterility: Methods to overcome incompatibility.

MODULE II **(7 hrs)**

Heterosis breeding, Polyploidy breeding, Induction of autopolyploidy and allopolyploidy, chromosome manipulation, Mutation breeding. Induction of mutations: Physical and chemical mutagens, Resistance breeding, Gene for gene systems of plants. Vertical and Horizontal resistance. Artificial production of epiphytotic conditions and screening procedures for resistance.

Molecular markers and their uses- Transgenic plants critical evaluation. Biometrical Techniques in Plant Breeding, Seed production and certification. Centers of crop breeding: International and National (with special reference to Kerala) IPR-Protection of plant variety and Plant breeder's Rights Act. National Biodiversity Policy.

MODULE III **(6 hrs)**

Horticulture: Concept and Scope, Plant growing structures – Greenhouse, Glasshouse and Mist chamber. Plant Propagation: Seed propagation and vegetative propagation- natural and artificial. Artificial methods of vegetative propagation, Cultural practices, Fertilizers: NPK, biofertilizers, green manure, compost, vermicompost. Outdoor horticulture, Types of gardens, Lawns and landscapes. Commercial horticulture, Indoor plants. Arboriculture Bonsai: Principles and procedure.

MODULE IV **(6 hrs)**

Animal Breeding: History and Classification of livestock breeds, Traits and economic importance of different species of livestock, Breeding/ Selection techniques for optimal production, Basis of Selection Sire evaluation, Response to the selection, selection differential and realized heritability, Multi-trait selection, Classification of mating systems, Inbreeding coefficient and coefficient of relationship, Linebreeding, Outbreeding, Outcrossing, Top crossing, Grading up, Criss-crossing, Rotational crossing, In-crossing and In-cross breeding, Species hybridization, Performance records and standardization, Heterosis- Definition, causes, measurement and its application in animal breeding, Breeding methods for improvement of dairy cattle and buffaloes, Conservation of germplasm, Current livestock and poultry breeding programme in the country.

MODULE V **(6 hrs)**

Aquaculture: Aquaculture practices and integrated fish farming, Culture, polyculture, the culture of shrimps, prawns, crabs, edible oysters, pearl oysters and mussels, seaweeds, freshwater fishes, cold water fishes, brackish water fishes. Preparation and maintenance of the aquarium. Preparation and maintenance equipment, water chemistry, aquarium fishes and plants pathology: Major fish diseases - viral, bacterial, fungal, protozoan infections, Control and treatment.

REFERENCES

1. Chopra, V. L. 2012. Plant Breeding Theory & Practice Oxford & Ibh Publishing Co Pvt Ltd
2. Chahal, G. S. & Gosal, S. S. 2002. Principles and Procedures of Plant Breeding. Narosa Publishing House.
3. Singh, B. D. 1996. Plant Breeding: Principles and Methods. Kalyani Publications.
4. Allard, R. W. 1995. Principles of Plant Breeding. John Wiley and Sons, Inc.
5. Sharma, J. R. 1994. Principles and Practices of Plant Breeding. Tata McGraw-Hill Publishers Company Ltd.
6. Hayward, M. D., Bosemark, N.O. & Romagosa, T. 1993 (Eds.) Plant Breeding. Principles and Prospects

SEMESTER VIII

BIO 10801- ADVANCED MICROBIOLOGY (3C= 48 hrs)

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.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**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	Create
C.O.3: Construct Antibiogram for analysis of the antibiotic profile of given pathogens-Disk diffusion method	Create
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 analyze the sequence data	Apply & Analyze
C.O.6: Isolate and quantitate pure metagenomic DNA from the soil sample.	Apply
C.O.7: Analyze the given metagenomic data set using bioinformatics tools to identify resistome, diversity and function	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1		x				
C.O.2						x
C.O.3						x
C.O.4		x				
C.O.5		x	x			
C.O.6		x				
C.O.7			x			

MODULE I **(10 hrs)**

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 **(10 hrs)**

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 virus, 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, COVID19

MODULE III: **(8 hrs)**

Mycology: Fungal diseases in plants and animals pathobiology, beneficial fungi, Antibiotic production, antibiotic resistance mechanisms and alternative measures.

MODULE IV **(10 hrs)**

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 **(10 hrs)**

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 analyze 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:

1. Pelczar, M. J., Chan, E. C. S., & Krieg, N. R. (2001). Textbook of microbiology. MC Graw-Hill publications, 5th edn, New York, 1193, 504-508.
2. Gibson, D. T. (1984). Microbial degradation of organic compounds. Marcel Dekker Inc.
3. Adams, M. R., & Moss, M. O. (2000). The microbiology of food preservation: In Food microbiology.
4. Davis B.D., Dulbecco R., Eisen H N.and Ginsberg H S.(1990). Microbiology.4th edition, J. B. Lippincott Company, Newyork.
5. Frazier, W. C., & Westhoff, D. C. (1988). Food microbiology 4th ed. Tata McGraw-Hill Publishing Co. Ltd. New Delhi.
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.
8. Ananthanarayan, R. (2005). Ananthanarayan and Paniker's textbook of microbiology. Orient Blackswan.
9. Pommerville, J. C. (2013). Fundamentals of microbiology. Jones & Bartlett Publishers.
10. Marjorie Kelly Cowan (2015).Microbiology: A Systems Approach,3rd edition, McGraw-Hill Higher Education.
11. Booth S J. (2010)Microbiology: Pearls of Wisdom, 2nd edition, Scientific book center.
12. Sherwood, L., Willey, J. M., &Woolverton, C. (2011). Prescott's Microbiology. McGraw-Hill.
13. Black, J. G. (2005). Microbiology: principles and explorations (Vol. 1). John Wiley & Sons Incorporated.
14. Hogg, S. (2013). Essential Microbiology. John Wiley & Sons.

BIO 10802- PLANT PHYSIOLOGY AND BIOCHEMISTRY (3C= 48hrs)

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.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	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.	Analyze
C.O.3: Explain the significance and transportation of mineral nutrition with respect to plants.	Understand
C.O. 4: Apply the knowledge on plant hormones for crop improvement in plant biotechnology	Apply
C.O. 5: Discuss the process of photosynthesis and the rate-limiting steps	Understand
C.O.6: Apply the knowledge of secondary metabolites and nitrogen fixation in agriculture welfare.	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4		x				
C.O.5	x					
C.O.6						

MODULE I **(10 hrs)**

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 **(10 hrs)**

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 **(10 hrs)**

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 **(10 hrs)**

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 **(8 hrs)**

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, 2003. Plant Physiology (III Edn). Panama 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.
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8. Plummer D T, 1988. An introduction to practical biochemistry. Tata McGraw-Hill Publishing Company, New Delhi.
9. Sadasivam S, Manickan A, 1996. Biochemical Methods. New Age International Ltd. New Delhi.
10. Salisbury F B, Ross C W, 1992. Plant Physiology. CBS Publishers and Distributors, Delhi.
11. Srivastava H S, 2005. Plant Physiology. Rastogi publications, Meerut.
12. Verma V, 2007. Textbook of Plant Physiology. Ane Books India, New Delhi.

BIO 10803- HUMAN PHYSIOLOGY AND ENDOCRINOLOGY (3C=48 hrs)

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 signaling pathways. Students will also study the influence of biological rhythm on hormone secretion.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**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
C.O.6. List the endocrine disorders and critically analyze their own and their family`s health issues.	Remember

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4	x					

C.O.5	x					
C.O.6				x		

MODULE I

(10 hrs)

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, atheroslecrosis, myocardial infarction, electrocardiogram, angiogram, angioplasty, Lymph and lymphatic system.

MODULE II **(10 hrs)**

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, haematurea, renal calculi, acidosis, and alkalosis-, fibrosis, Dialysis and kidney transplantation

MODULE III. **(10 hrs)**

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 **(8 hrs)**

Nerve Physiology: Structure of brain, Neurons-structure, types of neuron. Synapse and types of the synapse, nerve impulse propagation, synaptic transmission. Reflex action, refractory period, neurotransmitters, electroencephalogram. Nerve disorders- epilepsy, Alzheimer's disease, Parkinson's disease

MODULE V **(10 hrs)**

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 inter cerebralis-corpus cardiacum-corpus allatum complex, Prothoracic glands, endocrine disorders.

REFERENCES

Physiology

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.
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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. St. John ambulance associations' textbooks (a) First aid to the injured (b) A preliminary course of first aid to the injured.
13. Subramanyan, S. and Madhavankutty, K. (1977). The textbook of physiology, Orient LongmanLtd., New Delhi.
14. Vander, A.J., Sherman, J.H. and Luciano D.S. (1998), Human Physiology, MacGraw Hill Publishing Co., New Delhi.
15. Withers P.C. (1992). Comparative animal physiology. Saunders College Publishing

Fundamental Endocrinology

1. Hadley: Endocrinology (5th ed. 2000, Prentice-Hall)
2. Turner and Bagnara: General Endocrinology, 6th ed.1984, Saunders)
3. Norris: Vertebrate Endocrinology, Fourth Edition, 2007, Academic Press

BIO 10804- ETHOLOGY AND CHRONOBIOLOGY

Course objectives: Ethology is the study of animal behaviour and the wonderful ways in which animals interact with each other, with other living beings, and with the environment in which they live in. The behavioural biology has high applied value and is currently linked to conservation biology, molecular biology, behavioural ecology and integrated pest management. The chronobiology addresses some periodic and cyclic nature of various life phenomena occurring in living beings in nature. They often correlate with external environmental factors. This course aims to provide an overview of animal behaviour and chronobiology starting from a historical perspective to types of behaviours and their evolutionary significance.

Learning Outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1. Understand types of animal behaviour and their importance to the organisms.	Understand
C.O.2. Enhance their observation, analysis, interpretation and documentation skills by taking short projects pertaining to Animal behaviour and chronobiology.	Analyze
C.O.3. Relate animal behaviour with other subjects such as Animal biodiversity, Evolutionary biology, Ecology, Conservation biology and Genetic basis of the behaviour.	Apply
C.O. 4. Analyze the various process of chronobiology in their daily life such as jet lag.	Analyze
C.O.5. Describe biological rhythm and its application in pharmacology and modern medicine.	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3		x				
C.O.4					x	
C.O.5	x					

MODULE I **(8 hrs)**

Ethology: Concepts of Ethology, behaviourism and reaction to stimuli, Ethograms, Concepts of Fixed Action Patterns (FAP), Innate Releasing Mechanism (IRM), Action Specific Energy (ASE).

MODULE II **(10 hrs)**

Concepts of Learning and Imprinting, Motivating factors (guppies), Mating systems, Conflict behaviour, Instinctive behaviour & reflex action, the neural basis of sleep and arousal, Learning-Neural basis of learning, memory, cognition, sleep and arousal, Biological clocks, Adaptiveness of behaviour, JP Scott‟s categories of behaviour, External stimulus - circadian rhythms.

MODULE III **(10 hrs)**

Types of orientation-reafference theory of Von Holst & Mittel Steadt., Navigation & migration, Parental care, Development of behavior, Social communication; Social dominance; Use of space and territoriality; domestication and behavioural changes; Social behaviour of termites & Primates.

MODULE IV **(10 hrs)**

Evolution and adaptiveness of behaviour, Altruism, Kin selection, inclusive fitness, selfish gene theory, cultural transmission of behaviour, Hormones and Behaviour, Maternal behaviour-mechanism of hormonal action.

MODULE V **(10 hrs)**

Chronobiology: History, Biological rhythms, Biological clocks, Types, Significance, Measurement, properties, Factors influencing biological rhythms, zeitgebers, Centre and molecular basis of the biological clock, and its's applications.

REFERENCES

1. Alcock: Animal Behaviour- An Evolutionary Approach. (7th ed.) Sinaur Associates, Inc. 2001.
2. Drickamer & Vessey: Animal Behaviour –Concepts, Processes and Methods (2nd ed.), Wadsworth, 1986.
3. Gadagkar: Survival Strategies-Cooperation and Conflict in Animal Societies. Universities Press,1998.
4. Goodenough et al: Perspectives on Animal Behaviour, Wiley, 1993.
5. Grier: Biology of Animal Behaviour, Mosby, 1984.
6. Halliday and Slater: Animal Behaviour (vols. I-3) Blackwell Scientific Publ., 1983.
7. Krebs & Davis: Behavioural Ecology. (3rd ed.) Blackwell, 1993.

8. Lehner: Hand Book of Ethological Methods. (2nd ed.) Garland, 1996.
9. Manning & Dawkins: An introduction to Animal Behaviour (5th ed.), Cambridge Univ. Press, 1998.
10. Slater & Halliday: Behaviour and Evolution, (1st ed.) Cambridge Univ. Press, 1994.
11. Binkley, S. (1990): The clockwork sparrow: time, clocks, and calendars in biological organisms, Prentice-Hall, New Jersey.
12. Chandrashekaran, M. K. (1985): Biological rhythms, Madras Science Foundation, Chennai.
13. Shapiro, C. M. and Heslegrave, R. J. (1996): Making the shift work, Joli Joco Publications, Inc. Toronto.
14. Nelson, R. J. (2000) An Introduction to Behavioural Endocrinology, 2nd edition, Sunderland Publishers, Massachusetts.

BIO 10805- MICROBIOLOGY LAB **(2C= 32 hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	Cognitive Level
C.O. 1: Apply the basic microbiological techniques for media preparation, sterilization and isolation of bacteria and fungi from various surroundings	Apply
C.O. 2: Employ various biochemical techniques to characterize various microbes	Apply
C.O. 3: Evaluate the bacterial growth kinetics under different stress conditions	Evaluate
C.O. 4: Apply recombinant DNA technology technique to demonstrate the bacterial transformation in *E. coli*	Apply
C.O. 5: Evaluate the protein structures using spectroscopic platforms	Evaluate
C.O. 6: Evaluate the physical and chemical properties of DNA /proteins	Evaluate
C.O. 7**:** To identify the properties of different organic compounds using various spectroscopic techniques	Remember and Analyze

MAPPING OF CO’s AND PO’s

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1		x				
C.O.2		x				
C.O.3						x
C.O.4		x				
C.O.5						x
C.O.6						x
C.O.7				x	x	

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.
7. Mammalian virus culture and titration.

Biophysics and Bioinstrumentation

1. Effect of different solvents on UV absorption spectra of proteins.
2. Study of structural changes of proteins at different pH using UV spectrophotometry.
3. Study of structural changes of proteins at different temperatures using UV spectrophotometry.
4. Determination of melting temperature of DNA.
5. Study the effect of temperature on the viscosity of a macromolecule (Protein/DNA).
6. Use of viscometry in the study of ligand binding to DNA/protein.
7. Crystallization of enzyme lysozyme using hanging drop method.
8. Analysis, identification and comparison of various spectra (UV, NMR, MS, IR) of simple organic compounds.

BIO 10806- PLANT AND ANIMAL PHYSIOLOGY LAB (2C= 32 hrs)

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: To define the Photosynthetic phosphorylation process in plants	Remember
C.O. 2: Evaluate the total protein content in samples using biochemical techniques	Evaluate
C.O. 3: Evaluate the total chlorophyll and carotenoid content of leaf samples using different solvents	Evaluate
C.O. 4: Apply plant physiology principles to demonstrate osmosis, photosynthesis, transpiration and types of tropism in plants	Apply
C.O. 5: Apply the techniques of tissue sectioning and fixation for studying histology	Apply
C.O. 6: Applying the knowledge of blood typing for blood group identification	Apply
C.O. 7: Evaluating hormones using ELISA based techniques	Evaluate

MAPPING OF CO's AND PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1				x		
C.O.2						x
C.O.3						x
C.O.4		x				
C.O.5		x				
C.O.6		x				
C.O.7						x

Plant Physiology and Biochemistry

1. Experiment to demonstrate root pressure.
2. Extraction and estimation of total proteins by TCA precipitation and Lowry's method.
3. Isolation of chloroplast from fresh leaves and estimation of chlorophyll pigments.
4. Chlorophyll survey of five plants. Quantification, absorption spectra of chlorophyll and carotenoids using different solvents.
5. Hill activity by DCPIP/ ferricyanide reduction.
6. Setting up of Plant Physiology experiments.

7. Experiment to demonstrate endosmosis and exosmosis (Raisins and fresh grape experiment)
8. To demonstrate that xylem is the main path of movement of sap in the plant(Ringing experiment)
9. To demonstrate that oxygen is liberated during photosynthesis (Hydrilla experiment).
10. To demonstrate the effect of environmental factors on photosynthesis (Warm water,NaCl, KOH, chloroform, etc.) using hydrilla experiment.
11. Experiments to demonstrate the rate of transpiration is equal to the rate of water absorption.
12. To demonstrate the process of anaerobic respiration.
13. To study the R. Q. of different respiratory substrates by Ganong's respirometer.
14. Experiment to demonstrate gravity (Clinostat)

<u>Human Physiology and Endocrinology</u>

1. Preparation of temporary mounts: Neurons and Blood film.
2. Demonstration of haemoglobin using Sahli's haemoglobinometer.
3. Examination of permanent histological sections of mammalian, stomach, lung, kidney, thyroid, pancreas, testis, ovary.
4. Determination of ABO Blood group.
5. Recording of blood pressure using a Sphygmomanometer in resting condition.
6. Study of the permanent slides of all the endocrine glands
7. Estimation of plasma level of any hormone using ELISA
8. Chromatographic separation of steroid hormones using paper chromatography
9. Survey based project on any prevalent endocrine disorder

BIO 10807- RESEARCH METHODOLOGY/BIOETHICS/ BIOSAFETY/ IPR (2E= 32 hrs)

Course Description: This course introduces bioethics, biosafety and the IPR issues related to biotechnological research. It reviews ethical, legal and social issues and practices related to various applications of biotechnology including genetic testing and therapy, cloning, use of stem cells, etc. The practical aspects of performing responsible conduct of research will also be discussed. Discussion topics include biosafety issues regarding DNA research as well as the various guidelines. The course will also discuss the release of genetically modified organisms to the environment, its impact and safety issues. In addition, the role of IPR and the role of the patent in biotechnology and procedures for patenting and protection of traditional knowledge will be discussed.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1.Understand the ethical, moral, social and legal issues underlying products and processes developed by biotechnology and microbiology	Understand
C.O.2. Analyze and select appropriate biosafety measures for the conduct of experiments using various living organisms	Analyze
C.O.3. Apply the knowledge of Research Methodology to carry out research and document data in a systematic manner.	Apply
C.O. 4. Explain the process of risk assessment analysis of the release of genetically modified organisms	Understand
C.O. 5. Identify potential ethical issues in the conduct of research experiments and to avoid committing unintentional research misconduct	Understand & Apply
C.O.6. Understand the process of applying for a provisional and complete patent through national and PCT mode	Understand
C.O.7.Explain the various measures to protect to biodiversity and traditional knowledge from exploitation by unjust commercial interests	Comprehension

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3		x				
C.O.4	x					
C.O.5	x	x				
C.O.6	x					
C.O.7	x					

MODULE 1 **(6 hrs)**

Research Design, Conduct, Regulation, Recording & Presentation, Formulation of a research problem, Ethics and code of conduct in research, Data falsification, Plagiarism, Data security, Laboratory behavior, Biosafety and IT usage policy, Regulatory issues in Biotechnology, Maintenance of laboratory notebooks, Grant/Fellowship/Report writing, Manuscript Writing, Seminar Presentation.

MODULE II **(6 hrs)**

Literature Search, Use of Databases and Experimental Design, Databases for literature search, Bibliometrics, Citation, Impact factor, Hypothesis as a framework for scientific projects, Experimental design, taking measurements, Data Analysis, sampling, statistical tests with excel, handling data, hypothesis testing

MODULE III **(6 hrs)**

Good Laboratory Practices, Responsibilities of a researcher, handling and storage of biological material, laboratory waste disposal, management of personnel, facilities, buildings and equipment. Biosafety: Safety issues in different fields of Biotechnology, General Guidelines for recombinant DNA (rDNA) research, The Cartagena Protocol on Biosafety; NIH Guidelines; Guidelines for recombinant DNA research in India.

MODULE IV **(6 hrs)**

Classification of microorganisms according to pathogenicity; Containment facilities and Biosafety practices. Risk Analysis and Assessment: Release of GM organisms to the environment-Environmental Impact Assessment and risk analysis. Safety assessment of GMO foods and human clinical trials; GLP and GMP. Plant variety protection, Registration of newer varieties, Rights and obligations: Farmers and breeders rights. Protection of biodiversity, Convention on Biodiversity and the Indian Biodiversity Act, Protection of Traditional Knowledge.

MODULE V **(8 hrs)**

Bio-entrepreneurship and IP management in Biotechnology, Bio-entrepreneurship, Funding options, Introduction to Intellectual Property Rights, Types of IP, Patent search, IP management, Technology transfer therapy and genetic modifications, genetic testing and screening, human clinical trials and drug testing, bio-weapons program/bioterrorism.

REFERENCES

1. Research Methodology: Tools and Techniques Dr. Prabhat Pandey Dr. Meenu Mishra Pandey, 2015

2. Research Methodology-Methods and Techniques, 3rd edition, CR Kothari and Gaurav Garg

3. An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology, Padma Nambisan, 2017, Academic Press.

2. Textbook of Research Ethics - Theory and Practice, Sana Loue, 2002, Kluwer Academic Publishers.

3. Bioethics - An introduction, Marianne Talbot, 2012, Cambridge University Press.

4. Intellectual property rights in agricultural Biotechnology, F. H. Erbisch and K. M. Maredia, 2nd edition, 2003, Cambridge University Press.
5. The Cambridge Textbook of Bioethics, Ed. Peter A. Singer, 2008, Cambridge University Press.
6. Biotechnology, Biosafety and Biodiversity, Sivamiah Shantharam, Jane F. Montgomery, 1999, Oxford & IBH Publ. New Delhi.
7. Genetically modified Food Sources, Safety Assessment and Control, Tutelyal, VA, 1st edition, 2013, AcademicPress.
8. Bioethics: An Introduction to the History Methods and Practice, Jecker Nany S, Johnsen Albert, Perlman, Robert A, 2nd ed., 2010, John & Bartlett, New Delhi.
9. Environmental Safety of Biotech and Conventional IPM Technology, Sharma, HC Dhillon, MK, Sahrawat, KN, 2012, Stadium Press LLC. USA.
10. Bioethics and Biosafety, Sathish MK, 2008, IK International.
11. Intellectual Property Rights, Neeraj Pandey and Khushdeep Dharni, 2014, PHI Learning, Pvt. Ltd.

BIO 10808- BIOPHYSICS AND BIOINSTRUMENTATION (2E= 32 hrs)

Course description: Biological phenomena cannot be understood fully without physical insight. Biophysics is an interdisciplinary frontier of science in which the principles and techniques of physics are applied to understand biological problems at every level, from atoms and molecules to cells, organisms and environment. This paper covers various spectroscopic techniques, hydrodynamic methods, molecular biophysics and introduction to various physical principles responsible for maintaining the basic cellular function and integrity of biological membranes including transport across them.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1. Decribe the basic principles of light and electromagnetic waves and their applications in modern techniques	Understand
C.O.2. Explain the working principle of spectroscopy, CD, NMR, X-ray crystallography etc.	Understand
C.O.3. Calculate the nature of biomolecules using spectrometry	Apply
C.O.4. Explain the forces present in nature and their role in biomolecular interactions	Understand
C.O.5. Discuss the protein folding and the diseases associated with misfolding	Understand
C.O.6. Predict the structure of biomolecules using NMR	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2	x					
C.O.3		x				
C.O.4	x					
C.O.5	x					
C.O.6		x				

MODULE I **(6 hrs)**

Basic principles of electromagnetic radiation: Energy, wavelength, wavenumbers and frequency, review of the electronic structure of molecules. UV-visible spectrophotometry: Beer-Lambert law, chromophore, structural analyses of DNA/ protein using the absorption of UV light. Fluorescence spectroscopy: Theory of fluorescence, static and dynamic quenching, resonance energy transfer, fluorescent probes in the study of protein and nucleic acids. Mass spectrometry (MALDI-TOF): Physical basis and uses of MS in the analysis of proteins/ nucleic acids.

MODULE II **(6 hrs)**

Optical rotatory dispersion and Circular dichroism: Principle of ORD and CD, analysis of the secondary structure of proteins (denatured and native form) and nucleic acids using the CD. Infra-red spectroscopy: Theory of IR, identification of exchangeable hydrogen, number of hydrogen bonds, tautomeric forms. Magnetic resonance spectroscopy: Basic theory of NMR, chemical shift, medical applications of NMR.

MODULE III **(6 hrs)**

X-ray crystallography and Hydrodynamic methods: Diffraction, Bragg's law and electron density maps (the concept of R-factor and B-factor), growing of crystals (Hanging drop method). Viscosity: Methods of measurement of viscosity, specific and intrinsic viscosity, the relationship between viscosity and molecular weight, measurement of viscoelasticity of DNA. Sedimentation: Physical basis of centrifugation, Svedberg equation, differential and density gradient centrifugation, preparative and analytical ultracentrifugation techniques, fractionation of cellular components using centrifugation with examples.

MODULE IV **(8 hrs)**

Molecular biophysics: Basic thermodynamics: Concept of entropy, enthalpy, free energy change, heat capacity. Forces involved in biomolecular interactions with examples: Configuration versus conformation, Van der Waals interactions, electrostatic interactions, stacking interactions, hydrogen bond and hydrophobic effect. Supercoiling of DNA: Linking number, twist and writhe. Protein folding: Marginal stability of proteins, thermodynamic and kinetic basis of protein folding, protein folding problem (Levinthal's paradox), and role of molecular chaperones in cellular protein folding, basics of molecular and chemical chaperones, protein misfolding and aggregation, diseases associated with protein misfolding

MODULE V **(6 hrs)**

Flow Cytometry and Biological membranes: Basic principle of flow cytometry and cell sorting, detection strategies in flow cytometry. Biological membranes: Colloidal solution, Micelles, reverse micelles, bilayers, liposomes, phase transitions of lipids, transport of solutes and ions, Fick's laws of diffusion, ionophores, transport equation, membrane potential.

REFERENCE

1. Physical Biochemistry: Principles and Applications, 2nd edition (2009), David Sheehan, John Wiley. ISBN-13: 978-0470856031.
2. Physical Biochemistry: Applications to Biochemistry and Molecular Biology, 2nd edition (1982), David Freifelder, W.H. Freeman and Company. ISBN-13: 978-0716714446.
3. Physical Chemistry: Principles and Applications in Biological Sciences, 4th edition (2001), I. Tinoco, K. Sauer, J.C. Wang and J.D. Puglisi, Prentice-Hall, ISBN-13: 978-0130959430.
4. Molecular Biology of the Gene, 7th edition (2007), Watson, J. D., Baker T.A., Bell, S. P., Gann, A., Levine, M., and Losick, R, Benjamin Cummings Publishers, ISBN-13: 978-0805395921.
5. Biophysics, 1st edition (1983), W. Hoppe, W. Lohmann, H. Markl and H. Ziegler, SpringerVerlag, ISBN-13: 978-3540120834.
6. The Physics of Proteins: An Introduction to Biological Physics and Molecular Biophysics, 1st edition (2010), H. Frauenfelder, S.S. Chan and W.S. Chan, Springer, ISBN-13: 978-1441910431.
7. Principles of Instrumental Analysis, 6th edition (2006), D.A. Skooget. al., Saunders College Publishing. ISBN-13: 978-0495012016.
8. Principles of Physical Biochemistry, 2nd edition (2005), K.E. Van Holde, W.C. Jhonson and P. Shing Ho, Prentice Hall Inc. ISBN-13: 978-0130464279.
9. Biophysical Chemistry, 1st edition (1980), C.R. Cantor, P.R. Schimmel, W.H. Freeman and Company. ISBN-13: 9780716711889.
10. Crystallography Made Crystal Clear: Guide for Users of Macromolecular Models, 3rd edition (2010), Gale Rhodes, Academic Press. ISBN: 9780080455549.
11. Introduction to Protein Structure, 2nd edition (1999), C. Branden and J. Tooze, Garland Publishing, ISBN-13: 978-0815323051.

SEMESTER IX

BIO10901- IMMUNOLOGY (3C= 48 hrs)

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 'team-work' 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.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**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 'team-work' 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
C.O. 6. Assess the feasibility of adopting or adapting technologies from other disciplines in the correction and/or management of deranged immune systems.	Evaluate

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4		x				
C.O.5		x				
C.O.6						x

MODULE I **(10 hrs)**

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 **(10 hrs)**

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: **(10 hrs)**

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 centers, the role of HEV in lymphocyte trafficking; Immune responses against bacteria, fungi, parasites, viruses, and prions; Immune evasion strategies of pathogens.

MODULE IV **(8hrs)**

Clinical immunology: Immunodeficiencies; Hypersensitivity reactions; Autoimmune diseases; Transplantation immunology; Tumor immunology

MODULE V **(10 hrs)**

Immunoprophylaxis and Immunotechnology: 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 with respect to hypersensitivity, autoimmunity, transplantation, immunodeficiencies, and tumor immunology.

REFERENCES

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2. Murphy K., and Weaver, C., Janeway's Immunobiology 9th ed. 2017 Garland Science
3. J., Stanford, S., Jones, P., and Owen, J.A., Kuby Immunology 8th ed. (2019) PuntMacmillan Education
4. Male, D., Brostoff, J., Roth, D.B., Roitt, I.M. Immunology 8th ed. (2013) Elsevier
5. Mak, T.W., Saunders, M.E., and Jett, B.D., Primer to the Immune Response 2nd ed. (2014) Elsevier Inc.
6. Abbas, A.K., Lichtman, A.H., and Pillai, S., Cellular and Molecular Immunology 1st South Asia ed. (2017) Elsevier
7. Chakravarty, A.K. Immunology and Immunotechnology (2006) Oxford University Press
8. Flaherty, D.K Immunology for Pharmacy (2012)., Elsevier
9. Pathak, S., Palan, U., Immunology Essential and Fundamental 3rd ed. (2011) Capital Publishing Company
10. Chapel, H., Haeney, M., Misbah, S., and Snowden, N. Essentials of Clinical Immunology 6th ed. (2014) Wiley Blackwell
11. Sompayrac, L., How the Immune System Works 5th ed. (2016), Blackwell Wiley
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13. Bisen P.S., Laboratory Protocols in Applied Life Sciences (2014) CRC Press.
14. A Handbook of Practical and Clinical Immunology Vol. 1. And Vol 2. 2nd ed. (2017) Talwar G.P., and Gupta S.K., CBS Publishers

BIO10902- GENETIC ENGINEERING (3C= 48 hrs)

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.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**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	Create
C.O. 5. Construct a probe and do blotting techniques	Create
C. O.6. Apply site-directed mutagenesis technique	Create
C.O.7. Employ different types of PCR techniques for gene	Apply

amplification and clone the amplicon	
C.O.8. Demonstrate heterologous gene expression	Apply
C.O.9. Compare various genome editing tools	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2		x				
C.O.3		x				
C.O.4		x				
C.O.5		x				
C.O.6		x				
C.O.7		x				
C.O.8		x				
C.O.9					x	

MODULE I **(10 hrs)**

Enzymes in rDNA technology: Restriction–modification systems, Deoxyribo nucleases: exonucleases and endonucleases, Restriction enzymes-type-I, II, and III. S1 Nucleases, DNA Ligases, Alkaline phosphatase, DNA polymerase.

MODULE II **(10 hrs)**

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 **(10 hrs)**

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 **(10 hrs)**

Applications: PCR: RT-PCR, Inverse PCR, Nested PCR, LAMP; Molecular Markers - RAPD, RFLP, DNA fingerprinting, microsatellites and minisatellites, SNPs, ESTs, Barcoding; Site-directed mutagenesis; Gene transfer in animals and plants: direct gene transfer and molecular chimeras Microinjection, electroporation, biolistics, direct gene transfer using PEG, calcium chloride, calcium phosphate; Vector mediated gene transfer-Agrobacterium mediated transfer.

MODULE V **(8 hrs)**

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, meganucleases; MAGE; Applications

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BIO 10903- COMPUTATIONAL BIOLOGY (3C= 48 hrs)

Course description: An interdisciplinary program, this course emphasizes the integration of Computer Science with Biology and introduces the students to various computational methods and software tools for understanding biological databases, gene sequence alignments, gene annotation, protein structure predictions, drug discovery, molecular phylogeny, metagenomics, etc. The broad aim of this course is to make students get basic hands-on training and develop the skill-set required for computational analysis of biological data.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	Cognitive Level
C.O.1. Comprehend the amalgamation of computer tools for biological data analysis	Understand
C.O.2. Describe theoretically sources of biological data, and list various biological databases – nucleic acids, protein sequence, metabolic pathways and small molecule environmental issues and evaluate potential solutions	Understand
C.O.3. 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.4. Discuss the basics of computer languages like Python, Perl and Bio pearl	Understand
C.O.5: Apply the knowledge of languages in analyzing the data retrieved from the databases	Apply
C.O.6. Use the tools for analyzing the phylogeny	Apply
C.O.7. Apply R program and its application for statistical analysis of biological data and Next-generation sequencing	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4	x					
C.O.5		x				
C.O.6		x				
C.O.7		x				

MODULE I **(10 hrs)**

Basic algorithms in Computational Biology, Introduction to sequence alignment (only general ideas, not algorithm) - Local and global, pairwise and multiple, BLAST. Web programming and Databases, Introduction to Bioinformatics-Drug discovery, protein structure elucidation, molecular dynamic simulation, and genomic data analysis.

MODULE II **(8 hrs)**

Python Programming basics and biological application-next gen sequencing and big data management: Introduction to Python, Language Components: Functions Classes in Python, String Processing

MODULE III **(10 hrs)**

Perl and Bioperl programming and applications: Perl Basics: Evolution & Environment – Features of Perl; Scalar Data & Operators, Control Structures. Lists & Arrays, Array Functions, Associate Arrays, Arrays & Data Containers, Hash. Functions: User-defined functions – Built-in Functions, References, Regular Expressions – Processing Text with R.Es. Strings & Sorting Smart Matching, Perl Modules

MODULE IV **(10 hrs)**

Computational genomics, proteomics and CADD phylogenetics; To introduce basic genomic and transcriptomic sequence processing algorithms and concepts and impart skills regarding the use of popular software tools in this area. String view of DNA: Basic file formats: FASTA, GenBank, EMBL, GCG, PIR, Phylip, Nexus file formats etc. Sequence Data Bases, detailed study of GenBank of NCBI- typical Gen Bank (DDBJ+EMBL) for DNA and RNA, Sequence Representation & Analysis, Sequence alignment

MODULE V **(10 hrs)**

R programming, neural networks, machine learning and artificial intelligence; Introduction: R environment; Why R? R for Computational Biology and Bioinformatics; Installing R; R- GUI and IDE; Running R. Programming with R: R as a deluxe calculator, Objects: creating objects and assigning values, Types of objects: vector, matrix, array, factor, list, data frames and functions; Data structures, Control Statements in R, Graphics in R, statistics in R

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4. Attwood Teressa K. and David Parry- Smith (2007). Introduction to Bioinformatics. Pearson Education.
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BIO 10904- ENVIRONMENTAL BIOLOGY (3C= 48 hrs)

Course description: The primary aim of the syllabus is to sensitize the students about the paramount role and importance of nature. This course provides an introduction to the principles of environmental biology, ecology, and the relationship between humans and the natural world. This course will provide students with a broad survey of environmental science with an emphasis on scientific literacy, current events, global and international issues, and historic context. Biodiversity, conservation and biogeography are the other aspects of this course that will be addressed.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1. Comprehend the interactions and energy flow concepts integral to environmental science	Understand
C.O. 2. Analyze current environmental issues and evaluate potential solutions	Analyze
C.O. 3: Relate the features of human populations to different types of environmental degradation	Understand
C.O. 4: Assess the costs/benefits of conservation vs. remediation or technological solutions.	Analyze
C.O.5:Recognize the impact of globalization on the environment	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2		x				
C.O.3	x					
C.O.4		x				
C.O.5	x					

MODULE I **(10 hrs)**

Ecology: Biotic and abiotic factors and their interactions, structure, basic components, their interactions and inter-relations, Fundamental concepts relating to the energy-first and second law of thermodynamics, entropy. Gaseous and sedimentary cycles. Characteristics of the population: density, natality, mortality, biotic potential environmental resistance, growth forms, immigration, emigration and migration, Characteristics: species diversity, stratification, dominance, boundaries, ecotone and edge effect, ecological indicators, Ecological Energetics, Energy flow, primary and secondary productivity, standing crop, Food chain, food webs, trophic levels and ecological pyramids, Classification of ecosystems based on energy input.

MODULE II **(10 hrs)**

Transition and stability in communities, Succession-types, Trends, and Stages, Relevance of ecosystem development theory to human ecology, prospects for detritus agriculture, the compartment model, Species Interactions: Intra and interspecific interactions, Types of interspecific interactions, and coevolution.

MODULE III **(11 hrs)**

Biodiversity: Introduction, definition, levels of biodiversity (genetic diversity, species diversity and ecosystem diversity), values of biodiversity, Diversity indices: Alpha diversity, Beta diversity and gamma diversity; the species diversity and ecosystem stability, Biodiversity in India: Major biogeographic zones of India, hot spot biodiversity -characteristics; an outline of the features and biodiversity of hot spots in India (the Western Ghats and Himalaya), Features, structure and biodiversity of some of the Indian ecosystems; Terrestrial ecosystems (forest, grassland, desert), aquatic ecosystems, freshwater, marine estuarine

MODULE IV **(10 hrs)**

Conservation Biology-Depletion of biodiversity: Current estimates of species loss, causes of biodiversity loss, impacts of biodiversity loss, Strategic species concepts; keystone species, indicator species and umbrella/Flagship species. Strategies of conservation: in situ and ex situ conservation, gene banks, the establishment of protected areas, habitat conservation captive public awareness and other relevant measures.

1. An evaluation of the "Project Tiger' and "Project Elephant' programmes
2. World conservation strategy (1980)
3. National biodiversity action plan 2008: a brief outline of objectives and plans
4. International conventions and treaties for the conservation of biodiversity: Stockholm declarationon the human environment (1972), Convention on Regulation of Antarctic Marine Resources activities (RAMRA, 1986), World Charter for Nature (1982), Kyoto Protocol and Brundtland: framework Convention on Climate Change (UNFCCC) report 1987
5. Earth summit (1992)-detailed study-Ratio Declaration on environment and development,

Agendas 21, Forest principles, Convention on Biological diversity

6. Species based treaties: Migratory bird treaty act (MBTA) OF 1918, INTERNATIONAL CONVENTION for the Regulation of Whaling (ICRW), Washington, 1946, Convention for the conservation of Antarctic seals,1972, Convention on International Trade on Endangered species 1975
8. Ecosystem-based treaty: Ramsar convention, 1981-Ramsar sites in India and Kerala
9.

MODULE V **(8 hrs)**

Biogeography: Major terrestrial biomes, Savanna Biogeographical zones of India, Applied Ecology, Carbon credit, Carbon trading, Blue Carbon, Green building technology and its ecological importance. Interlinking of major rivers of India, Sethusamudram ship canal project. Biodiversity with special reference to India-status, monitoring and documentation, major drivers of biodiversity change, Major approaches to management, Indian case studies on conservation & management strategy (concepts of project tiger, Biosphere reserves). Phytogeography**-** concept & definition. Vegetation in India Phytogeographical regions of India

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BIO 10905- IMMUNOLOGY LAB (2C= 32 hrs)

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Evaluating the blood cell indices using a haemocytometer	Evaluate
C.O. 2: To define the basic principles of heaemagglutination and immunodiffusion	Remember
C.O. 3: To evaluate antibodies or complement proteins attached to blood cells using diagnostic techniques	Evaluate
C.O. 4: To define the basic principles of immunoelectrophoresis	Remember
C.O. 5: To apply knowledge of molecular biology and immunogenetics to detect specific proteins using western blotting techniques	Apply
C.O. 6: To evaluate and quantifying peptides, proteins, antibodies and hormones using the ELISA technique	Evaluate
C.O. 7: Evaluating the variations in the immune system	Evaluate

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1						x
C.O.2				x		
C.O.3						x
C.O.4				x		
C.O.5		x				
C.O.6						x
C.O.7						x

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)

BIO 10906- GENETIC ENGINEERING AND COMPUTATIONAL BIOLOGY LAB
(2C= 32 hrs)

Genetic Engineering

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: To apply basic principles of molecular biology to isolate DNA from different tissue samples	Apply
C.O.2: To apply molecular biology and recombinant DNA technology to study transformation and plasmid DNA isolation	Apply
C.O.3: Apply Recombinant DNA technology to demonstrate restriction and ligation of DNA	Evaluate
C.O.4: Apply techniques of molecular biology for extracting RNA and cDNA from leaf samples	Apply
C.O.5: Apply Polymerase chain reaction techniques to demonstrate the various type of PCR techniques	Apply
C.O.6: Evaluate the expression kinetics of various genes using Quantitative PCR	Evaluate
C.O.7: To define various sequencing platforms of DNA	Remember

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1		x				
C.O.2		x				
C.O.3						x
C.O.4		x				
C.O.5		x				
C.O.6						x
C.O.7				x		

1. Isolation of genomic DNA (Bacteria, bacteriophage, plant and rat liver) and isolation of metagenomic 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 – BOX, ERIC, Nested
8. Real-time PCR (demonstration)
9. LAMP (demonstration)
10. DNA sequencing (demo by industrial visit)

Computational Biology

1. Facilitating access from various Bioinformatics databases: NCBI, PDB, SWISS PROT, Pfam, etc., and pairwise sequence alignment using BLAST.
2. Database creation and management using PHP-MySQL,
3. Writing programs using python features including functions, string handling as well as object-oriented features,
4. Data analysis using the R statistical software
5. Data analysis using Perl programming language
6. Validating DNA/ RNA/ Amino acid sequences,
7. Finding complement & reverse complement of DNA sequence,
8. Writing a sequence in Fasta format,
9. Computing the nucleotide composition of a given DNA sequence.
10. Computing the amino acid composition of a given protein sequence. : Finding the AT Composition of a given DNA sequence, Finding the GC Composition of a given DNA sequence, Finding the ORFs in a given DNA sequence, Transcribe a DNA sequence into RNA.
11. PERL: Translate the given DNA sequence into the corresponding amino acid

sequence

12. Mapping amino acid sequence with different physiochemical features like hydrophobicity, finding n-mer frequencies in DNA and amino acid sequence

Molecular Taxonomy

I. Familiarising with molecular marker-based techniques,

1. RFLP
2. RAPD,
3. AFLP,
4. SSR
5. ISSR
6. SCAR
7. SNPs

II. Prediction of the evolutionary link and phylogenic relationship of plants and animals from their genomic data

III. Study the biogeographic distribution of flora and fauna in Kerala, India via molecular taxonomy

Genomics and Proteomics

1. Find the secondary and tertiary structure of the given protein sequence.
2. Design primer for mitochondrial COX1 gene
3. Analyze the metagenomics data of soil microbiome for resistome, diversity and function
4. Analyze the transcriptomics data of soil for expression of resistance components
5. Design drugs for a given cancer marker as a receptor
6. Docking of the given ligand on the receptor and find the interactions

BIO 10907- GENOMICS AND PROTEOMICS (2E= 32 hrs)

Course description: In this course, we use the genomics approach to understand the proteome, predict protein structure from DNA sequence data, understand protein-protein interactions, and use of different tools for the analysis of genomic data sets. Besides, this course also includes the methods for gene annotation to gene prediction.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1 Understand Protein sequencing, Nucleic acid sequencing and their analysis.	Understand
C.O. 2 Analyze Gene expression and establish the genomic library	Analyze
C.O. 3: Design primer for a specific marker gene	Apply
C.O. 4: Describe proteins interaction, activity, modification and function	Understand
C.O. 5: Apply Protein modeling and molecular dynamics methods to study structure from sequence	Apply
C.O.6: Discuss the Design drugs from data of functional genomics and proteomics	Understand
C.O.7: Analyze the metagenomics data of soil microbiome for resistome, diversity and function	Analyze
C.O.8: Analyze the transcriptomics data of soil for expression of resistance components	Analyze

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2					x	
C.O.3		x				
C.O.4	x					
C.O.5		x				
C.O.6	x					
C.O.7					x	
C.O.8					x	

MODULE I **(6 hrs)**

Visualization and protein structure prediction: Protein structure prediction for known folds and unknown folds (secondary structure prediction, prediction of transmembrane regions, homology modeling); Online modeling servers (e.g.-SWISSMOD), Molecular visualization software-Kinemages and chemscape, Chime molecular visualization, Rasmol, pymol, Discovery Studio.

MODULE II **(6 hrs)**

Structural proteomics: Methods of sequence-based protein prediction. Definition of protein families – protein families and classification, SCOP and CATH, patterns, profiles, sequence vs family comparison. Homology modeling, prediction of protein structure from sequences, functional sites, FSSP, 3Dee

MODULE III **(6 hrs)**

Protein folding: Protein folding problem, protein folding classes, protein identification and characterization:- AACompIdent, TagIdent, PepIdent and MultiIdent, PROSEARCH, PepSea, PepMAPPER, FindPept, Predicting transmembrane helices.

MODULE IV **(8 hrs)**

Tools and methods in genomics: Stand-alone packages for sequence alignment- Bioedit, MEGA, Submitting, DNA sequence in Genbank - bankIt, Sequin, tbl2asn, Primer designing, Tools for primer designing. Gene ontology and annotation; Prediction of genes and protein-coding regions, Conserved sequence pattern discovery; Tools for gene prediction; Whole-genome analysis; Gene mapping; Genome sequencing strategies, Next Generation Sequencing platforms, Transcriptome sequencing- *de novo* and resequencing, Metagenomics - MG-RAST.

MODULE V **(6 hrs)**

Drug designing: Introduction, Structure-based drug designing approaches Target Identification and Validation, receptor mapping, active site analysis and pharmacophore mapping, Grid maps. Introduction to docking methods to generate new structure; Tools and Molecular docking programs: AutoDock, Dock, HEX, Cheminformatics.

REFERENCES

1. Lesk, A. (2019). Introduction to bioinformatics. Oxford university press.
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BIO 10908- MOLECULAR TAXONOMY **(2E= 32 hrs)**

Course Description: This course aims to provide an understanding of taxonomy at the molecular level. The course in deeper insight into the taxonomical concept, aids and tools for classification, nomenclature, characterization of biodiversity. In addition, it will provide the current trends of systematic tools based on a computer algorithm and molecular markers.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1 Understand the advanced level of systematics concepts and tools	Understand
C.O. 2 Identifying the taxonomical position of living forms based on the advanced taxonomical tools.	Apply
C.O. 3: Differentiate and classify various life forms in the basis of their molecular architecture.	Analyze
C.O. 4: Employ computer-aided algorithms for profiling of genomic data for taxonomical purpose.	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2		x				
C.O.3	x					
C.O.4		x				
C.O.5	x					

MODULE I **(6 hrs)**

Introduction: Definition and basic concepts in Systematics and Taxonomy, Levels of Taxonomy: Alpha, Beta and Gamma taxonomy, Importance and applications of taxonomy, Goals of taxonomy, Definition of systematics, Definition of classification, Species: Monotypic species, Polytypic species, Ecospecies and Cenospecies, Morphospecies, Super species, Species as a Population Complex, Species Concepts: Typological Species Concept, Nominalistic Species Concept, Biological Species Concept, Evolutionary Species Concept, Difficulties in the application of the biological species concept

MODULE II **(6 hrs)**

Classification: Classification, Purpose of Classification, Theories of Classification: (a) Essentialism (b) Nominalism (c) Empiricism (d) Cladism (e) Evolutionary Classification Hierarchy of Categories: The objectives of classification, Taxonomic Collections and the Process of identification, Taxonomic collections: Types of collections, Value of Collection, Purpose of scientific collection, Preservation of Specimens, Labeling; Curating of collections, Curating of types, Identification- Methods of identification, Use of keys, types of keys, Merits and demerits of different keys, Description and publication

MODULE III **(7 hrs)**

Taxonomic Characters: Nature of taxonomic characters, Taxonomic characters and adaptation, Kinds of taxonomic characters (a) Morphological (b) Physiological (c) Ecological (d) Ethological and (e) Geographical Characters, Taxonomic characters and classification, Taxonomic characters and evolution, Functions of taxonomic characters, Zoological Nomenclature, Brief History of nomenclature, International Code of Zoological Nomenclature, The nature of scientific names,

Species and infraspecies names, Gender of generic names, Synonyms and Homonyms, The Law of Priority, Rejection of names: Type method and different kinds of types

MODULE IV **(6 hrs)**

Newer trends in systematics: Chemotaxonomy and serotaxonomy, Cytotaxonomy, Numerical taxonomy, Cladistics, Molecular Taxonomy, Molecular Phylogenetics, phylogenetic trees, molecular markers (allozyme markers, microsatellite, arbitrary nuclear markers, and neutral markers), Advantages of molecular data, DNA Barcoding, sine differential OCR, Multiplex PCR, RFLP, AFLP, RAPD, Quantitative PCR, LAMP.

MODULE V **(7 hrs)**

Regulations in Taxonomy: Ethics related to taxonomic publications, Authorship of taxonomic papers, Correspondence, Suppression of data, Undesirable features of taxonomic papers, Taxonomist and user communities, Taxonomic impediments, Impediments in taxonomic collections and maintenance, Shortage of manpower, lack of funding for taxonomic research, Lack of training and library facilities, Impediments in publishing taxonomic work, Solutions to overcome the impediments, Improve international co-operation (b) Development of taxonomic centers.

REFERENCES

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Associates, Inc.
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   NY.9. Mayr, E.1997. this is Biology: The Science of Living world. Universities Press Ltd.

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11. Pat Willmer. 1996. Invertebrate Relationships-patterns in animal evolution. Cambridge University Press Vertebrate Paleontology. Blackwell Publishing Com. Oxford, UK

SEMESTER X

BIO 11001 INNOVATION AND ENTREPRENEURSHIP FOR BIOLOGISTS (2E=32 hrs)

Course Description: The objective of this course is to expose the students to the field of innovation and entrepreneurship with a specific focus on life science. Student will also be familiarized with the process of developing a life science enterprise. In this course you will learn the tools and trades of becoming an entrepreneur. Course will teach you the various aspects of entrepreneurship; from the fundamentals of selecting an idea and developing a product or process; Preparing a business plan to Identifying and securing investors; setting up a company to meeting the regulatory requirements. Student teams will perform various activities of entrepreneurship: from identifying a market need after market survey and coming up with a solution to making a business plan and pitching to investors.

This course is conducted jointly by Department of Biotechnology and School of Management Studies at CUSAT and outside resource persons experienced in life science entrepreneurships and soft-skill training who will be invited for discussion/workshops. This course will be conducted in workshop mode. Case studies will be included with active participation. The practical component will include case studies, discussions, brainstorming, presentations, etc.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1: . Describe the various programmes and opportunities for entrepreneurship in life science in India	Understand
C.O.2: Apply innovation tools such as ideation and design	Apply

thinking for generating innovative ideas	
C.O.3: Analyse real time data to explore and establish relationships in the areas of entrepreneurship decisions	Analyze
C.O.4: Identify potential funding sources and how to sell the idea for successful funding	Apply
C.O.5: Evaluate various business ideas in the field of life science and select the most appropriate one on the basis of opportunity identification, opportunity evaluation and feasibility studies	Evaluate
C.O.6: Generate new bio-entrepreneurship ideas and create business plans and proposals for starting business or business expansion/ diversification.	Create

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**
C.O.1	x					
C.O.2		x				
C.O.3					x	
C.O.4		x				
C.O.5						x
C.O.6			x			

MODULE I **(6 hrs)**

Innovation and entrepreneurship: Invention-innovation differences; Types of innovation; creativity; innovation ecosystem; challenges of innovation management; steps in innovation management; technology and innovation- new business models. State and scope of life science innovations and entrepreneurship in India and the world; unique opportunities and challenges of Bio-entrepreneurship.

MODULE II **(6 hrs)**

Entrepreneurship: Definition, traits, characteristics, qualities and functions of entrepreneurs; Entrepreneurial Behaviours and entrepreneurial motivation; Entrepreneurship Theories; Entrepreneurship types: Social entrepreneurship and Technology entrepreneurship, Family business; Start-up landscape and innovation hubs; Innovation in Indian context.

MODULE III **(6 hrs)**

Entrepreneurship: Role in economic development. Entrepreneurial climate in India; Ease of doing business, Government support for entrepreneurship, Start-up India Programme, Pradhan Mantri Mudra Yojana, Assistances for Biotech enterprises, BIRAC/BIG, Business Incubation and other schemes. MSME Policy: various schemes and support.

MODULE IV **6 hrs)**

Idea generation: Design thinking, customer journey mapping, Idea evaluation; lean start-up; Business plan: elements-technical-marketing-financial, preparation of Business plans.

Sources of Finance: Venture capital, angel investment, crowd funding. Mechanics of setting of new enterprises – forms of business organization.

MODULE V **(8 hrs)**

Protection of Intellectual Property Rights, Patent, Trademark and Copyrights. Managerial problems of new enterprises; production purchasing, financing labour and marketing problems.

REFERENCES

1. Innovation and Entrepreneurship, Drucker, Peter, 1985, Heinemann, London.
2. Patterns of Entrepreneurship Management, Kaplan, J.M and Warren A.C., John, 2013, Wiley & Sons Inc.
3. Entrepreneurship Development and Small Business Enterprises, Charantimath Poornima M, 2018, Pearson.
4. The Lean Start Up, Ries, Eric, 2011, Crown Publishing, USA.
5. Entrepreneurial Policies and Strategies- The Innovator's Choice, Manimala, Mathew J, 1999, SAGE Publications.
6. The IDEATE Method, Identifying High-Potential Entrepreneurial Ideas, Cohen, Dan Pool, Greg & Neck, Heidi, 2020, SAGE Publications.
7. Managing Innovation and Entrepreneurship, Kearney, Claudine & Hisrich, Robert D, 2013, SAGE Publications.
8. Biotechnology Entrepreneurship - Starting, Managing, and Leading Biotech Companies, Ed. Craig Shimasaki, 2014, Academic Press.
9. Art of the Start 2.0, Guy Kawasaki, 2015, Portfolio.
10. A Biotech Manager's Handbook - A Practical Guide, Eds. M O'Neill M M Hopkins, 2012, Woodhead Publishing
11. Innovation, Commercialization, and Start-Ups in Life Sciences, James F. Jordan, 2014, CRC Press.
12. Enterprise for Life Scientists: Developing Innovation and Entrepreneurship in the Biosciences, Adams, D. J., & Sparrow, J. C., 2008, Bloxham: Scion.

BIO 11002- DISSERTATION **(16C)**

BIO 11003 VIVA **(2C)**

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Syllabus of Chemistry

SEMESTER: 5

Semester Credit: 20 (Core: 20; Elective: 0) Cumulative Credit:116

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10501	Analytical Chemistry-I (Analytical Techniques, Instrumental Methods, Molecular Spectroscopy)	Core	3	3-1-0	50	50	100
CHE 10502	Inorganic Chemistry-I (Chemistry of Main Group Elements)	Core	3	3-1-0	50	50	100
CHE 10503	Organic Chemistry-I (Functional Group Chemistry)	Core	3	3-1-0	50	50	100
CHE 10504	Physical Chemistry-I (Equilibrium Thermodynamics)	Core	3	3-1-0	50	50	100
CHE 10505	Mathematics for Chemists	Core	2	2-1-0	50	50	100
CHE 10506	Inorganic Chemistry Lab	Core	2	0-0-6	100	-	100
CHE 10507	Organic Chemistry Lab	Core	2	0-0-6	100	-	100
CHE 10508	Open Ended Lab-I	Core	2	0-0-6	100	-	100

SEMESTER: 6

Semester Credit: 20 (Core: 20; Elective: 0) Cumulative Credit:136

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10601	Inorganic Chemistry-II (Coordination Chemistry)	Core	3	3-1-0	50	50	100
CHE 10602	Organic Chemistry-II (Structure, Stereochemistryand Conformational Analysis)	Core	3	3-1-0	50	50	100
CHE 10603	Physical Chemistry-II (Electrochemistry, SolidState and Liquid State)	Core	3	3-1-0	50	50	100
CHE 10604	Industrial Chemistry	Core	3	3-1-0	50	50	100
CHE 10605	Computer Programming andNumerical Methods	Core	2	2-1-0	50	50	100
CHE 10606	Advanced Physical Chemistry Lab-I	Core	2	0-0-6	100	-	100
CHE 10607	Industrial Chemistry Lab	Core	2	0-0-6	100	-	100
CHE 10608	Open Ended Lab-II	Core	2	0-0-6	100	-	100

SEMESTER: 7

Semester Credit: 21 (Core: 16; Elective: 5) Cumulative Credit:157

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10701	Inorganic Chemistry -III (Concepts and Developments)	Core	3	3-1-0	50	50	100
CHE 10702	Organic Chemistry-III (Reactivity and Mechanisms)	Core	4	4-1-0	50	50	100
CHE 10703	Theoretical Chemistry-I (Quantum Chemistry)	Core	3	3-1-0	50	50	100
CHE 10704	Theoretical Chemistry-II (Group Theory and Spectroscopy)	Core	4	4-1-0	50	50	100
CHE 10705	Advanced Chemical Synthesis and Separation Lab	Core	2	0-0-6	100	-	100
CHE 10706	Open Ended Lab-III	Core[c]	-	-	0-0-6	-	-
CHE 10707	Supramolecular Chemistry	Elective	3	2-1-0	50	50	100
CHE 10708	Green Chemistry	Elective	3	2-1-0	50	50	100
CHE 10709	Polymer Chemistry	Elective	3	2-1-0	50	50	100
CHE 10710	Bonds and Bands in Solids	Elective[a]	2	2-1-0	50	50	100
CHE 10711	Professional and Career Development in Chemistry	Audit [b]	-	2-0-0	-	-	-

SEMESTER: 8

Semester Credit: 20 (Core: 16; Elective: 4) Cumulative Credit:177

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10801	Inorganic Chemistry-IV (Chemistry of d- and f-Block Elements)	Core	3	3-1-0	50	50	100
CHE 10802	Organic Chemistry -IV (Reactions,Reagents and Synthesis)	Core	4	4-1-0	50	50	100
CHE 10803	Organic Chemistry -V (Spectroscopy of Organic Compounds)	Core	2	2-1-0	50	50	100
CHE 10804	Physical Chemistry-III (Statistical and Nonequilibrium Thermodynamics)	Core	3	3-1-0	50	50	100
CHE 10805	Theoretical Chemistry-III (Chemical Bonding and Computational Chemistry)	Core	2	1-1-3	50	50	100
CHE 10806	Advanced Physical Chemistry Lab-II	Core	2	0-0-6	100	-	100
CHE 10807	Open Ended Lab-IV	Core[c]	-	0-0-6	-	-	-
CHE 10808	Bioanalytical Chemistry	Elective	2	2-1-0	50	50	100
CHE 10809	Advanced Photochemistry	Elective	2	2-1-0	50	50	100
CHE 10810	Theory of Orbital Interactions in Chemistry	Elective	2	1-1-3	50	50	100

SEMESTER: 9

Semester Credit: 23(Core: 17; Elective: 6) Cumulative Credit:198

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10901	Analytical Chemistry-II (Advanced Analytical Techniques and Instrumental Methods)	Core	4	4-1-0	50	50	100
CHE 10902	Inorganic Chemistry -V (Organometallic and Bioinorganic Chemistry)	Core	3	3-1-0	50	50	100
CHE 10903	Organic Chemistry-VI (Chemistry of Natural Products)	Core	3	3-1-0	50	50	100
CHE 10904	Physical Chemistry-IV (Chemical Kinetics, Reaction Dynamics, Catalysis and Surface Chemistry)	Core	3	3-1-0	50	50	100
CHE 10905	Physical Chemistry-V (Advanced Electrochemistry)	Core	2	2-1-0	50	50	100
CHE 10906	Open Ended Lab-V	Core	2	0-0-6	100	-	100
CHE 10907	Oleochemicals, Nutraceuticals, Surfactant Technology	Elective	2	2-1-0	50	50	100
CHE 10908	Materials Chemistry	Elective	2	2-1-0	50	50	100
CHE 10909	Chemical Crystallography	Elective[a]	4	4-1-0	50	50	100

SEMESTER: 10

Semester Credit: 16 (Core: 16; Elective: 0) Cumulative Credit : 216

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 11001	Project Dissertationand Viva Voce	Core	16	-	-	300	300

a-MOOC Course
b-Value Added Course
c-evaluation in third semester
L-T-P ≡ Lecture-Tutorial-Practical Hours

CE ≡ Continuous Evaluation; ESE ≡ End Semester Evaluation

Detailed Syllabus of Chemistry (V,VI,VII,VIII,IX,X)

CORE

CHE 10501

ANLYTICAL CHEMISTRY-I

(ANALYTICAL TECHNIQUES, INSTRUMENTAL METHODS, MOLECULARSPECTROSCOPY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Perform various statistical evaluation of experimental data	Analyse
C.O. 2: Explain the theory, instrumentation and applications of various chromatographic, spectroscopic, thermal and surface analytical methods	Apply
C.O. 3: Predict the type of spectroscopic/chromatographic method forthe analysis of the given compound/mixture	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x									
C.O.2	x	x								
C.O.3	x	x	x							

UNIT – 1 **(6 hrs)**

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- Students t test, f test, Criteria for rejecting a value-Q test, Confidence interval, Correlation and Regression, Linear regression analysis

UNIT – 2 **(10 hrs)**

Chromatography-classification-column, paper, thin layer chromatography, selection of mobile and stationary phase, Theory and instrumentation of HPLC, LC-MS, GC, GC-MS, ion exchange chromatography, gel permeation chromatography, supercritical fluid chromatography and size exclusion chromatography, Important applications of chromatographic techniques Solvent extraction and Solid phase extraction Distribution law-Liquid-liquid extractions, synergistic extraction. Counter current extraction, super critical fluids, Electrophoresis- theory and applications.

UNIT – 3 **(12 hrs)**

Introduction to spectroscopy, spectroscopy and its importance in chemistry, interaction of electromagnetic radiation with matter, Difference between atomic and molecular spectra. Energy levels in molecules, different types of spectroscopic techniques, Basic instrumentation of spectrometers, optical systems used in spectroscopy – Sources, Filters, Monochromators, Detectors, Single and Double beam optics, Signal to noise ratio, bandwidth and band pass. Instrumentation of NMR, FT IR, UV-Visible, Laser Raman spectroscopy and fluorescence spectroscopy.

UNIT – 4 **(10 hrs)**

Atomic absorption spectroscopy – Absorption of radiant energy by atoms,Instrumentation, Interferences in AAS, Analytical applications of AAS.

Atomic Emission spectroscopy – Principle – Types – Flame atomic emissionspectroscopy, Flame photometry, ICP-AES

Instrumentation and applications of ICP-AES

UNIT – 5 **(10 hrs)**

Introduction to surface characterisation techniques-SEM, AFM, TEM, XRDPrinciple and applications of SEM, TEM, AFM and XRD Introduction to thermal methods of analysis-TG, DTA and DSC

Recommended Text Books:

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

CORE

CHE 10502

INORGANIC CHEMISTRY – I

(CHEMISTRY OF MAIN GROUP ELEMENTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Describe the general periodic behaviour and occurrence of themain group elements	Understand
C.O. 2: Interpret the types of bonding based on the electronicconfiguration	Apply
C.O. 3: Explain the reactivity and physicochemical properties based on the type of bonding	Analyse
C.O. 4: Compare the structure, bonding and reactivity of the main group elements with the related organic compounds and transition metal complexes	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					

UNIT – 1 **(12hrs)**

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^+ ionsin solution, Alkali metal complexes, Organolithium compounds.

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

UNIT – 2 **(12 hrs)**

p- Block elements – Group 13 elements- General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, oxides, halides, Complex Compounds, Chemistry of oxidation states I and II, Boranes- Preparation, Classifications, Structure and Bonding, Tetrahydroborate ion, Boron Halides, Boron – Nitrogen Compounds, Boron – Oxygen Compounds.

Organometallic compounds of Al Group 14 elements – General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Carbon- Properties, Allotropes, Carbon Halides, Carbon Oxides, Compounds with C-N bond, C-S bond, Carbon compounds as ligands. Oxygencompounds of Silicon, Organo compounds, Silanes and Silenes, Organometallic compounds of Si and Sn. Inorganic Polymers,

UNIT – 3 **(8 hrs)**

Group 15 elements - General Behavior, Occurrence and abundance, Group trends and stereochemistry, Electronic Configuration and types of bonding, Active Nitrogen, Nitrogen fixation natural and artificial, Nitrogen compounds- Nitrides, Ammonia, Hydrazine, Oxides of Nitrogen, Oxo acids and anions, Halogen Compounds, nitrogen compounds as ligands, Halides of Phosphorous, Oxides of Phosphorous, Sulfides and other chalcogenides of phosphorous, Phosphonium, Phosphorous – Nitrogen Compounds, Phosphorus-nitrogen compounds: Phosphazenes and poly phosphazenes. Organic compounds of Phosphorous, Compounds with element-element bonds, Oxo anions of Phosphorous, Phosphate in bio systems, Phosphorous compounds as ligands, Compounds of Ar, Sb and Bi.

UNIT – 4 **(8 hrs)**

Group 16 elements - General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Group trends and stereochemistry, Types of oxides, Chemical properties of Dioxygen, Singlet oxygen, ozone, Peroxo compounds, Superoxide, Halo compounds, Oxygen compounds as ligands, Sulfanes, polysulfides, 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}. Halogen compounds of sulphur, Oxides, oxohalides and oxo acids of Sulphur, Sulphur compounds as ligands.

UNIT – 5 **(8 hrs)**

Group 17 elements- General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Halogen bonding, Preparation, C-T complexes of Halogen, Halides, Molecular halides, Halides and halogen compounds as ligands, Oxides and oxo acids, Interhalogen and poly halogen compounds, Oxohalogen fluorides. Group 18 elements - General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Halogen compounds.

Recommended Text Books:

1. Mingos, D. M. P., Essential Trends in Inorganic Chemistry, OxfordUniversity Press 1998.
2. Wulfsberg G., Inorganic Chemistry, VIVA, 2002.
3. Greenwood, N. N., Earnshaw, A., Chemistry of the Elements, MaxwellMacmillan 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

CORE

CHE 10503

ORGANIC CHEMISTRY-I
(FUNCTIONAL GROUP CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Correlate structure of organic compounds with their properties	Apply
C.O. 2: Describe the synthesis and reactions of different classes of organic compounds	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x									
C.O.2			x				x	x		

UNIT – 1 **(8 hrs)**

Alkyl and aryl halides - Classification, physical properties, preparation methods, reactions.

UNIT – 2 **(10 hrs)**

Alcohols, phenol and ethers - Classification, physical properties, preparation methods, reactions – with hydrogen halide, order of reactivity of 1^o, 2^o and 3^o alcohols, with PCl_3, dehydration, with active metals, ester formation, formation of alkyl sulfonates, oxidation – primary, secondary and tertiary alcohols, chemoselective oxidants for alcohols – Oppenauer's oxidation, Moffatt-Pfitzner oxidation, Des-Martin oxidation, Alcohols as acids and bases. Ascent and decent in alcohol series Dihydric alcohols: Oxidative cleavage– Lead tetra acetate, Periodic acid- Pinacol - Pinacolone rearrangement –mechanism.

Phenols - Preparation, physical properties, - Acidity of phenols, reactions, Semester 5 rearrangement of phenol derivatives-Fries rearrangement, Claisen rearrangement

Ethers – preparation, physical properties, reactions – cleavage by acids. Synthesis and Reactions of Epoxides, Cleavage of ether linkages by HI- Zieselsmethod of estimation of methoxy groups.

UNIT – 3 **(10 hrs)**

Carbonyl compounds A: Aldehydes and Ketones

Physical properties, preparation, reactions – Cannizaro reaction, Aldol condensation, Wittig reaction, nucleophilic addition - addition of cyanide, derivatives of ammonia, Grignard reagent, alcohols, oxidation and reduction – Baeyer-Villiger oxidation-Cannizzaro's reaction, Meerwein-Ponndorf Verley reduction, Clemmensen reduction, Wolff-Kishner reduction, $LiAIH_4$ and $NaBH_4$ reductions, α, β – unsaturated carbonyl compounds – Claisen, Claisen-Schmidt, Dieckmann, Benzoin, Aldol, Perkin and Knoevenagel condensations, nucleophilic and electrophilic addition – Michael addition and Robinson annulation, Mannich reaction. Alkylation of carbonyl compounds *via* enamines.Compounds containing active methylene groups.

UNIT – 4 **(10hrs)**

Carbonyl compounds B: Carboxylic Acids and acid chlorides & esters

Physical properties – Acidity of carboxylic acids – effect of substituents, preparation, reactions – salt formation and decarboxylation, preparation and reactions of functional derivatives, halogenation of aliphatic acids - Hell- Volhard- Zelinsky reaction.

Methods of formation and chemical reactions of anthranilic acid, cinnamic acid, acrylic acid, oxalic acid, malonic acid, citric acid, adipic acid, maleic acid, fumaric acid. Preparation and reactions of benzene sulphonic acid, benzene sulphonyl chloride and ortho and para toluene sulphonyl chlorides- uses. Esters, hydroxyl acids, lactones.

Synthetic uses of malonic ester, acetoacetic ester and cyanoacetic ester. Keto-enoltautomerism of ethyl acetoacetate

UNIT – 5 **(10 hrs)**

Nitrogen containing compoundsAmines- isomerism- stereochemistry of amines, distinguish between primary, secondary and tertiary amines- Structural features affecting basicity of aliphatic and aromatic amines. Quaternary amine salts as phase-transfer catalysts. Comparative study of aliphatic and aromatic amines. Preparation of alkyl and arylamines (reduction of nitro compounds, nitriles), reductive amination of aldehydic and ketonic compounds, Gabriel-Phthalimide reaction, Diazonium salts-preparation, synthetic transformations of aryl diazonium salts, azo coupling-Mechanisms of Sandmeyer's and Gatterman reactions- Schiemann and Gomberg reactions Preparation and uses of Phenyl hydrazine. Diazomethane and diazoacetic ester -preparation, structure and synthetic uses -Arndt Eistert synthesis- mechanism –Wolff rearrangement. Amides - preparation and reactions.

Recommended Text Books:

1. Bruice, P.Y. Organic Chemistry, 7th Ed., Prentice Hall Inc., 2013.
2. Morrison, R.T. Boyd, R.N. and Bhattacharjee, S.K. Organic Chemistry, 6th Ed.,
3. Pearson Education Inc., 2014.
4. Clayden, J. Green, N. Warren, S. and Wothers, P. Organic Chemistry, 2nd Ed.,Oxford University Press, 2012.
5. McMurry, J. Organic Chemistry, 5th Ed., Brooks/Cole, 2000.
6. Bruckner, R. Advanced Organic Chemistry: Reaction Mechanisms, 1st Ed.,Academic Press, 2001.
7. Carey, F.A. and Sundberg, R.J. Advanced Organic Chemistry (parts A and B), 5th Ed., Springer, 2008.
8. Norman, R.O.C. Principles of Organic Synthesis, 2nd Ed., Chapman and Hall,1978.
9. Solomons, T.W.G. Fryhle, C.B., Snyder, S. A. Organic Chemistry, 12th Ed.,Global, 2017.
10. Smith Janice G., Organic Chemistry 3rd Edn., McGraw-Hill, 2011.

CORE

CHE 10504

PHYSICAL CHEMISTRY- I

(EQUILIBRIUM THERMODYNAMICS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Predict changes in thermodynamic parameters during a process and predict the spontaneity.	Apply
C.O. 2: Describe the significance of chemical potential in physical and chemical processes	Apply
C.O. 3: Understand thermodynamics of phase transitions and interpret phase diagram of a given system.	Analyse
C.O. 4: Interpret dependence of chemical equilibrium on pressure, temperature and concentration.	Analyse

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					

UNIT – 1 **(8 hrs)**

Language and Mathematics of Thermodynamics.

Recap of first and second law. The Clausius inequality, Free energy functions - Variation with temperature and pressure. Gibbs Helmholtz equation. Relationbetween thermodynamic functions. Maxwell relations-significance. Third law of thermodynamics: Nernst Heat Theorem, Calculation of absoluteentropy, Unattainability of absolute zero.

UNIT – 2 **(10 hrs)**

Thermodynamic systems of variable composition – Partial molar properties. Chemical Potential, Significance of Chemical potential, Gibbs Duhem Equation and Duhem Margules Equation. Thermodynamics of mixing. Excess functions, Concepts of activity and fugacity, Standard states.

UNIT – 3 **(10 hrs)**

Physical transformation of Pure substances- Stability of a phase, Phase transitions and phase boundaries- Thermodynamic aspects, Ehrenfest Classification of Phase transitions. Phase rule – Application to one component systems- Water, S, CO_2 and He.

UNIT – 4 **(10 hrs)**

Thermodynamics of Binary systems: Binary liquids- Ideal solutions, Raoults law, Henry's Law, Deviations from ideality, Real and Regular solutions, Excess functions, Ideal Dilute Solutions-Colligative Properties- van't Hoff factor.

Liquid-vapour equilibria of binary systems – Vapour pressure-composition diagrams and Temperature composition diagrams. Distillation of binary mixtures –Azeotrope formation.

Liquid-liquid equilibria- Partially miscible and immiscible liquids- CST, Nernst Distribution Law, Partition co-efficient, Principle of Steam distillation.

Solid-liquid Equilibria-Cooling curve, Eutectic system, Deep Eutectic solvents, Application, Compound formation with Congruent and Incongruent melting points. Salt hydrate water systems,

Solid-Vapour Equilibria- $CuSO_4$-water system. Three component systems.

UNIT – 5 **(10 hrs)**

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

Recommended Text Books:

1. Peter Atkins and Julio de Paula, Physical Chemistry, Oxford University Press, 8th and 10th Edn, 2017.
2. D.A McQuarrie, J.D Simon, Molecular Thermodynamics, Viva Student Edn.2010.
3. I.N Levine, Physical Chemistry, McGraw Hill Indian Edn, 2011.
4. I. M. Klotz & R. M. Rosenberg, Chemical Thermodynamics, Wiley, 7th Edn, 2008.
5. L. K. Nash, Elements of Chemical Thermodynamics, Addison Wesley, 2nd Edn, 2013.
6. F. Daniels and R. A. Alberty, Physical Chemistry, Wiley Publishers, 4th Edn2004

CORE

CHE 10505

MATHEMATICS FOR CHEMISTS

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Solve mathematical problems	Apply
C.O. 2: Apply the principles of mathematics to chemicalsystems/processes	Analyse

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x								
C.O.2	x	x								

UNIT – 1 **(4 hrs)**

Numbers: Real and Complex number algebra. Vector algebra.

UNIT – 2 **(6 hrs)**

Functions & Variables: Differential calculus-first- and higher-order derivatives, evaluation of minimum and maximum, limits & continuity. Partial differentiations. Exact and inexact differentials. Numerical differentiation. The gamma and delta functions.

Integral Calculus: Indefinite and definite integrals, improper integrals. Methods of integration. Surface and volume integrals. Numerical integrations.

UNIT – 3 **(8 hrs)**

Differential Equations: Ordinary first- and second-order differential equations. Partial differential equations. Solution of inexact differential equations by the method of integrating factors. Power series and extended power series solutions. Numerical solutions.

UNIT – 4 **(8hrs)**

Special functions: Hermite, Legendre and Laguerre polynomials, recursion relations. Matrices and Determinants. Eigenvalues and eigenvectors. Orthogonal transformation. Rank & inverse of matrix.

UNIT – 5 **(6 hrs)**

Solution of Linear Systems: Gaussian elimination, Cramer's rule. Gauss-Jordan elimination. Gauss-Seidel and Jacobi methods. Solution of non-Linear Systems: Newton-Raphsonmethod. Curve fittings. Permutation & Combination. Probability. Stirling's approximation. Lagrangemultipliers.

Recommended Text Books:

1. Mortimer, R. G, Mathematics for Physical Chemistry. 3rd Edn., AcademicPress.2014
2. Kreyszig, E., Advanced Engineering Mathematics. 9th Edn. Wiley,2015
3. Turrell, G., Mathematics for Chemistry and Physics, 2nd Edn., AcademicPress,2004
4. McQuarrie, D. A., Mathematics for Chemists and Physicists, 4th Edn., Wiley,2007

CORE/LAB

CHE 10506

INORGANIC CHEMISTRY LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Estimate the amount of a given metal ion bycomplexometric reactions	Apply
C.O. 2: Identify the cation from the given mixture	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x		x	x					
C.O.2	x	x	x	x	x					

UNIT – 1 **(96 hrs)**

1. Complexometry
2. Estimation of Zinc Estimation of Magnesium
3. Estimation of different metal ions from a mixture – use of masking agents
4. Analysis of less common ions
5. Separation and identification of two less familiar metal ions such as Tl,W, Se, Mo, Ce, Th, Ti, Zr, V, U and Li from a mixture of salts.

Recommended Text Books:

1. Vogel's Textbook of Quantitative Chemical Analysis 6th Ed., PearsonsEducationLtd.
2. A.I. Vogel, G. Svehla, Vogel's Qualitative Inorganic Analysis, 7th Edn., Longman,1996.
3. V.V. Ramanujam, Inorganic Semimicro Qualitative Analysis, The NationalPub.Co., 1974.
4. Laboratory Manual, CHE 10506, Department of Applied Chemistry, CUSAT

ORGANIC CHEMISTRY LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Prepare organic compounds through one step synthesis andpurify and recrystallize the product	Analyse
C.O.2: Apply analytical techniques for the quantitative and qualitative analysis of organic molecules	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x		x						
C.O.2	x	x		x						

UNIT – 1 **(96 hrs)**

One step synthesis of Organic Compounds Estimation of organic compounds Separation of organic binary mixtures–liquid-liquid extraction, columnchromatography. Purity assessment of the isolated components by TLC & GC.

Recommended Text Books:

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. Dey, B.B. Sitaraman, M.V. and Govindachari, T.V. Laboratory Manual of OrganicChemistry, 3rd Ed., Viswanathan, 1957.
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. Mann, F.G. Saunders, B.C. Practical Organic Chemistry, 4th Ed., PearsonEducationIndia, 2009.
5. Clark, H.T. A handbook of organic analysis, Longman, 1966.
6. Laboratory Manual, CHE 10707, Department of Applied Chemistry, CUSAT.

CORE/LAB

CHE 10508

OPEN ENDED LAB-I

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independentresearch problem.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validatingthe hypothesis.

The students shall submit a project report and appear for viva-voce.

CORE

CHE 10601

INORGANIC CHEMISTRY – II

(COORDINATION CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Explain the properties of transition metals and lanthanides	Apply
C.O.2: Describe and explain the structure, bonding and magnetism in transitionmetal complexes using crystal field theory and ligand field theory	Analyse
C.O. 3: Describe various metal-ligand interactions in terms of sigma- and pi-bonding	Evaluate
C.O. 4: Explain the stability of transition metal complexes, their reactivity, and the mechanisms of ligand substitution and redox reactions	Analyse

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					

UNIT – 1 **(8 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. Lanthanides and Actinides- Stable oxidation states, lanthanide and actinide contraction, Occurrence and recovery; Separation of Lanthanides; difference between 4f and 5f orbitals.

UNIT – 2 **(10 hrs)**

Werner's theory, Bonding in coordination compounds: Valence bond description and its limitations. valence bond theory (inner and outer orbital complexes), Crystal Field Theory (CFT). measurement of 10 Dq (Δ_o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δ_o, Δ_t). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, Jahn – Teller effect in octahedral complexes, square planar geometry.

UNIT – 3 **(10 hrs)**

Factors affecting the crystal-field parameters. Spectrochemical series, colour and spectral behaviours. magnetism of first-row transition metal complexes, stabilization of unusually low and high oxidation states of metals, Ligand field theory and Qualitative aspect of MO Theory, Effect of π-donor and π- acceptor ligands in LFSE, back bonding. Application of crystal filed theory, lattice energies, ionic radii, site preferences in spinels. Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

UNIT – 4 **(12 hrs)**

Definition and Classification with appropriate examples based on nature of metal-carbon bond (ionic, s, p, and multicentre bonds), metal-metal multiple bonding, Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, EAN rule as applied to carbonyls, electron count ofmononuclear, polynuclear and substituted metal carbonyls of 3d series. Preperation and Structures 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. Zeise's salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls. Organo-lithium aluminium, magnesium, zinc and titanium compounds – their preparations, properties, reactions, bonding and applications. "Sandwitch'' compound: Ferrocene – its preparation, reactions and structure.

UNIT – 5 **(8 hrs)**

Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans-effect, theories of trans effect, Mechanism of nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Labile and inert complexes, Kinetics of octahedral substitution, Ligand field effects and reaction rates.

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, Principleand structure and reactivity, 4th Ed., Harper Collins College Publishers, NewYork, 1993.
3. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry 2nd Ed.,University Science Books, 1994.
4. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed.,Wiley-Interscience, 1999.
5. Basolo, F, and Pearson, R.C., Mechanisms of Inorganic Chemistry, 2nd Ed.,John Wiley & Sons, NY, 1967.
6. Greenwood, N.N. & Earnshaw A., Chemistry of the Elements, 2nd., Ed.Butterworth-Heinemann,1997.
7. Miessler, G.L. & Tarr, D. A. Inorganic Chemistry, 5th Ed., PearsonPublication, 2013.
8. Sharpe, A.G. Inorganic Chemistry, 4th Indian Reprint, Pearson Education,2005.
9. Douglas, B. E.; McDaniel, D.H. and Alexander, J.J. Concepts and Modelsin Inorganic Chemistry 3rd Ed., John Wiley and Sons, NY, 1994.
10. Powell, P. Principles of Organometallic Chemistry, 2nd Ed., Springer, 1991.

11. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4thEd., W.H. Freeman & Company, 2006.
12. Crabtree, Robert H. The Organometallic Chemistry of the Transition Metals.6th Ed., New York, NY: John Wiley, 2014.
13. W. L. Jolly, Modern Inorganic Chemistry, McGraw-Hill International, 2ndEdition, New York, 1991.

CORE

CHE 10602

ORGANIC CHEMISTRY-II (STRUCTURE, STEREOCHEMISTRY AND CONFORMATIONAL ANALYSIS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Appraise Molecular Orbital Theory and group orbital concepts tosketch MO's of common organic molecules and reactive intermediates	Analyze
C.O.2: Apply the concepts of isomerism and analyse the conformation andconfiguration of organic molecules.	Apply
C.O.3: Analyze the conformational effects on the reactivity of various reactions	Analyze
C.O.4: Understand the conformation and stereo-electronic effects of carbohydrates	Understand

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		

UNIT – 1 **(10 hrs)**

MO theory and Frontier orbitals: Qualitative Molecular Orbital Theory, Group orbitals, Hyper conjugation, Negative – Hyperconjugation, Anomeric effect. Conjugated Systems, Huckels rule and Modern theory of Aromaticity. Substituent effects on frontier orbitals. Study of Structure and Stability of Reactive intermediates: Carbocations, Carbanions, Carbenes, Nitrenes, and Radicals.

Study of Bonding Weaker than Covalent Bonds: Ion pairing interactions, ion – dipole interactions, dipole – dipole interactions, Hydrogen bonding, Factors affecting strength and stability of hydrogen bonds, cations – π, polar – π, π- stacking, π-donor – acceptor interactions, induced dipole interactions, the hydrophobic effect.

UNIT – 2 **(10 hrs)**

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

Brief introduction to CD and ORD techniques, octant rule, axial haloketone rule, and sign of Cotton effect

UNIT – 3 **(8 hrs)**

Conformational analysis: Strain, types of strain including *B, F, I*, Pitzer strain, Beyer strain. Acyclic sp^3–sp^3, sp^3-sp^2 systems, structure and stability of small, medium, and large rings, cyclohexane, substituted cyclohexanes, *A* values, cyclohexenes, decalins, bicyclic systems.

UNIT – 4 **(10hrs)**

Reaction Mechanisms and Conformational Effects on Reactivity - Ester Hydrolysis, Alcohol Oxidations, S_N2 Reactions, Elimination Reactions, Epoxidation by Intramolecular closure of Halohydrins, Epoxide Openings (S_N2), Electrophilic Additions to Olefins, Rearrangement Reactions, Conformational and Stereoelectronic Effects on Reactivity. Baldwins rules for ring closure.

UNIT – 5 **(10 hrs)**

General introduction to carbohydrates: Structure and stereochemistry of monosaccharides, disaccharides, mutarotation, glyoxal, stepping up and stepping down, reducing and non-reducing sugars, glycosidic linkage, O & N glycosides. Conformation and Stereo-electronic Effects of carbohydrates: *D* and *L* sugars, Chair conformation, Endo/Exo-anomeric effect, Reverse anomeric effect, Glycosidic torsion angles, Hydroxymethyl group conformation. Conformationand stability of aldohexoes,structure and conformation of ribose and deoxyribose.

Recommended Text Books:

1. March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure,7th ed. 2013, Wiley
2. T H. Lowry and K.S. Richardson: Mechanism and Theory in OrganicChemistry, 3rd ed. 1997, Benjamin-Cummings Publishing Company.
3. F. A. Carey and R. J. Sundberg: Advanced Organic Chemistry (parts A and B),5th Edition 2008, Springer.
4. E. V. Anslyn and D. A. Dougherty: Modern Physical Organic Chemistry. Ist ed.2006, University Science Books,
5. F. A. Carroll: Perspectives on structure and mechanism in organic chemistry, 2ndedition, 2011 Wiley.
6. N. S. Issacs: Physical Organic Chemistry, Second Edition, 2nd Edition, 1995, Prentice Hall.
7. A. Pross: Theoretical and Physical Principles of Organic Chemistry, IEdition,1995, Wiley.
8. J. Clayden, N. Green, S. Warren and P. Wothers: Organic Chemistry, 2ndEdition. 2012, Oxford University Press,
9. P.S.Kalsi: Stereochemistry, Conformation and Mechanism, 3rd Edn., New Age Publications
10. E. L. Eliel and S. H. Wilen: Stereochemistry in Organic Compounds, 1994, John Wiley.

11. S. H. Pine: Organic Chemistry, 5th edition, 2008, McGraw Hill
12. I. Flemming: Molecular orbitals and organic chemical reactions, student edition,2009, Wiley.
13. J. McMurry, Organic Chemistry, Fifth Edition, 2000, Brooks/Cole .
14. D. Nasipuri, Stereochemistry of Organic Compounds: Principles and Applications, Second Edition, 1994, Wiley Eastern Limited, New Delhi.

CORE

CHE 10602

PHYSICAL CHEMISTRY- II

(ELECTROCHEMISTRY, SOLID STATE AND LIQUID STATE)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Describe the theories effecting ionic conductance and apply the concepts to calculate conductance of a given system.	Apply
C.O. 2: Describe the mechanism of electronic conductance process in charged interfaces.	Apply
C.O. 3: Describe the regular arrangement of atoms in crystals and the symmetry of their arrangement	Analyse
C.O. 4: Understand properties of solids and liquids, and see how their mechanical, electrical, optical, and magnetic properties stem from the properties of their constituent atoms and molecules.	Analyse

	Programme Outcomes									
Course	**P.O.**	**P.O.**	**P.O.**	**P.O.**	**P.O.**	**P.O.**	**P.O.**	**P.O.**	**P.O.**	**P.O.**

Outcomes	1	2	3	4	5	6	7	8	9	10
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					

UNIT – 1 **(8 hrs)**

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.

UNIT – 2 **(12 hrs)**

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 co-efficient, 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)

UNIT – 3 **(12 hrs)**

Symmetry as a universal theme, Molecular symmetry, Symmetry elements and operations, Point groups, Matrix representation of symmetry operations, character, Definition of a mathematical group, Abelian group, Cyclic group, symmetry operations as group elements, symmetry and isomerism, Symmetry classification of molecules into point groups (Schoenflies symbol). Group multiplication table. 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

UNIT – 4 **(8 hrs)**

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.

UNIT – 5 **(8 hrs)**

Vapour pressure , Surface tension - determination of vapour pressure. Parachor – determination, application to structure elucidation of compounds, Viscosity - determination of molecular mass from viscosity measurements. Refraction – refractive index, molar refraction and optical exaltation – application to structure elucidation, Concept of super hydrophobicity/super-leophilcity.

Recommended Text 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, 4thedn, 1994.
3. S. Glasstone, An Introduction to Electrochemistry, Paperback edn., 2007
4. L.V. Azaroff, Introduction to Solids, Mc Graw 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.

CORE

CHE 10604

INDUSTRIAL CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe the sustainable management of chemicals	Apply
C.O.2: Preform quality analysis of chemical products	Analyse
C.O.3: Evaluate the factors influencing the industrial scale up of chemicalsynthesis	Evaluate
C.O.4: Explain and prepare flow chart for preparation of chemicals	Analyse

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x		x	x	x	x	x		
C.O.2	x	x		x	x	x	x	x		
C.O.3		x		x	x	x	x	x		
C.O.4		x	x	x	x	x	x	x		

UNIT – 1 **(10 hrs)**

Source of Chemicals, Organic Chemicals, Inorganic Chemicals, Recycling of materials, waste minimization, E factor and atom economy, Reduction of- material use. Water management – water for industry, sources of water, water conditioning methods, municipal waste water, Industrial waste water – treatment. Energy Management- energy required by chemical industries, sources of energy, cost of energy, types of energy requirement, use of energy, efficient utilization of energy., energy, risk and hazards. Sustainable use of- chemical feedstocks, water, energy. Environmental pollution control – methods of pollution control, economics of pollution control, industrial health and hygiene.

UNIT – 2 **(10 hrs)**

Industrial Processes in practice – Basic chemical data, Flow charts; chemical process selection, design and operation, Plant location, safety, construction of plant, process system engineering. Case study of chemical industry of regional importance. Pharmaceutical Industries – Classification, methods of preparation, radioisotopes in medicine, biological hormones, steroids, vitamins, plant and animal isolates, drug design (basic understanding)

UNIT – 3 **(10 hrs)**

Fuel Industries – Calorific value, modern concept of fuels, classification, criteria for selection, comparison of gas, liquid and solid fuels, properties, methods of processing various fuels, solid fuels , Gaseous fuels, Petroleum – occurrence, mining, product of refining, Processing, color and constituency, classification and composition, grading of petroleum, determination of flash point, knocking, antiknock compounds, octane number, cetane number, chemical treatment to upgrade liquid fuel, Petrochemicals.

UNIT – 4 **(10hrs)**

Agrichemical Industries- Fertilizers – Fertilizer type, need for fertilizer, essential requirements, plant nutrients and regulators, soil fertility, pH of soil, classification of fertilizer, natural fertilizers, nitrogenous fertilizer, Phosphate fertilizers, NPK fertilizers, effect of fertilizer- pollution. Insecticides- classification, DDT, BHC, Gammexane, Endosulfan. Attractant and repellants.

Introduction to nutraceuticals: definitions, synonymous terms, claims for a compound as nutraceutical, regulatory issues. Study of Properties, structure and functions of various Nutraceuticals (3 examples) formulation of functional food, stability, analysis. Food as remedies, Anti-nutritional Factors present in Foods, Nutraceutical Industry and Market Information.Syntheticuses of malonic ester, acetoacetic ester and cyanoacetic ester. Keto-enol automatism of ethyl acetoacetate.

UNIT – 5 **(8 hrs)**

Rubber Industries – Chlorinated and oxygenated rubber, latex, coagulation, crude natural rubber, vulcanization, physical and chemical properties. Synthetic rubbers- SBR, silicone rubber, reclaimed rubber, foam rubber, rubber cement, applications, Rubber derivatives. Leather – manufacture, tanning of leather – vegetable tanning, chrome tanning, oil tanning. Synthetic Fibers – properties, preparation, requirements, difference between synthetic and natural fiber. Rayon, Nylon, Orlon, Teflon.

Recommended Text Books:

1. C. A. Heaton, An Introduction to industrial chemistry, 2^{nd} edition,1991,Blackie.
2. George T. Austin, Shreve's Chemical Process Industries, 5^{th} edition, 1984,McGraw Hill International.
3. B. K. Sharma, Industrial Chemistry (including Chemical Engineering), 1997, GOEL Publishing House.
4. M. Farhat Ali, Bassam El Ali, Handbook of Industrial Chemistry: OrganicChemicals, 2005, McGraw Hill Professional.
5. Fritz Ullmann, Ullmann's Encyclopedia of Industrial Chemistry, 1999-2014,John Wiley and Sons,Inc.
6. A. K. De, Environmental Chemistry, 7^{th} edition, 2013, New AgeInternational Publishers.
7. G. E. J. Poinern, A Laboratory Course in Nanoscience and Nanotechnology,2015, CRC Press Taylor & FrancisGroup.

CORE

CHE 10605

MATHEMATICS FOR CHEMISTS

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Describe different numerical methods and apply them to solve simple chemical problems	Apply
C.O. 2: Write FORTRAN programmes for solving simple chemical problems using the numerical methods	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x								
C.O.2	x	x					x			

UNIT – 1 **(6 hrs)**

Programming in FORTRAN: Program design (algorithm), organization of program, data types and integer constants, complex constanta, logical constants, variables, implicit and explicit data typing, expressions and hierarchy of operations, mix-mode arithmatic, library functions, input/output specification, formatting, unconditional transfers, conditional statements and constructs, GO TO/ IF statements, relational operators, block if structure, else if construct, do loops, nesting, variables and arrays, parameter/data statements, common blocks, read/write by opening files, subroutines and construction of largeprogram.

UNIT – 2 **(6 hrs)**

Numerical Methods: Taylor's theorem, Expansion of functions, Remainder, Mean value and Extreme value theorems, Discrete average value theorem. Numerical Differentiation (first, second and higher derivatives) - Truncation and Round-off errors, Step size dilemma, Difference table (Pascal's triangle).

UNIT – 3 **(4 hrs)**

Numerical Integration - Riemann sum, Quadrature rule, Interpolating polynomials (Lagrange's), Weights, Mid-point, Trapezoidal, Simpson's rule of integration, Adams' Predictor-Corrector method. Roots of equations- Newton- Raphson and Secant methods, Bisection and False-point methods, Bracketing method.

UNIT – 4 **(8hrs)**

Numerical solution of ordinary differential equations- Initial value problems, Euler's method, Taylor and Runge-Kutta methods, Modified Euler and Hugen's method, Error estimates. Curve fitting- Least square fit algorithm, Monotone and convex data. Linear systems- Forward, Backward substitution, LU- factorization, pivoting (only basics), Gaussian Elimination, Gauss-Jordan Elimination, Jacobi and Gauss-Seidel methods. Eigenvalue problems. Statistical analysis of data.

UNIT – 5 **(8 hrs)**

Programming Laboratory (Linux OS, vi editor): Students are instructed to write programs on some of the numerical methods taught. Programming in FORTRAN (FORTRAN 77 Standard) Examples of numerical algorithms – algebraic equations, numerical integration, curve fitting, matrix computations.

Recommended Text Books:

1. Schatzman, M., Numerical Analysis: A Mathematical Introduction, 2nd Edn. Oxford University Press,2012
2. McCormick, J. M., Salvadori, M. G., Numerical Methods in Fortran, Prentice Hallof India,2009
3. Burden, R. L., Faires, J. D., Numerical Analysis, 2nd Edn. Brooks/Cole,2012.

4. Epperson, J. F., An Introduction to Numerical Methods and Analysis, John Wileyand Sons, Inc.,2014
5. Maron, M. J., Numerical Analysis: A Practical Approach, , Macmillan,2008.
6. Hildebrand, F. B., Introduction to Numerical Analysis, McGraw Hill, New York,2007.
7. Xavier, C., Fortran 77 and Numerical Methods, 2nd Edn., New Age International Publishers,2011
8. Rajaraman, V., Computer Programming in Frotran, PHI Learning,1995.10. Mollah,S.A.,Numerical Analysis and Computational Programming, Allied Publishers Ltd,2011

CORE/LAB

CHE 10606

ADVANCED PHYSICAL CHEMISTRY LAB – I

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Verify the concepts and laws in physical chemistry	Evaluate
C.O.1: Execute and perform experiments based on CST, Rast method, Transition temperature and Hall effect for the determination of various physical properties	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1 **(96 hrs)**

1. Enzyme Kinetics
2. C.M.C. determination
3. CST
   Determination of mutual solubility of phenol-water system Influence of KCl, Succinic acid on CST of phenol-water system- Estimation of concentration of unknown solution
4. RAST METHOD
   Determination of molal depression constant of naphthalene -determination of molecular weight of solute
5. TRANSITION TEMPERATURE
   Determination of transition temperature of salt hydrate-water system Determination of molecular weight of solute ;Viscosity, molecular weight of polymers
6. Intermolecular hydrogen bonding in benzyl alcohol using infrared spectroscopy
7. HALL EFFECT EXPERIMENT

Recommended Text Books:

1. J. N. Gurtu, and A. Gurtu Advanced Physical Chemistry Experiments, 6th Ed., Pragati Prakashan,2014.
2. J. B. Yadav, Advanced Practical Physical Chemistry, 36th Ed., KrishnaPrakashan, 2016.
3. Laboratory Manual, CHE 10606, Department of Applied Chemistry, CUSAT.

CHE 10607

INDUSTRIAL CHEMISTRY LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Prepare and analyze industrially important chemical products	Create
C.O. 2: Prepare the treatment methods for conversion ofnatural resources to value added chemicals	Create

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1			x	x				x	x	
C.O.2			x	x				x	x	

UNIT – 1 **(96 hrs)**

1. Preparation of soap anddetergents
2. Preparation ofmargarine
3. Preparation and physical property measurement of natural, syntheticrubber,fiber.
4. Extraction of essentialoils
5. Extraction of naturalflavors
6. Preparation of Biogas
7. Waste watertreatment
8. Preparation and characterization ofnanomaterials
9. Preparation of silicon from RiceHusk
10. Galvanization/powder coating

Recommended Text Books:

1. J. N. Gurtu, and A. Gurtu Advanced Physical Chemistry Experiments, 6th Ed., Pragati Prakashan,2014.
2. J. B. Yadav, Advanced Practical Physical Chemistry, 36th Ed., KrishnaPrakashan, 2016.
3. Laboratory Manual, CHE 10606, Department of Applied Chemistry, CUSAT

CORE/LAB

CHE 10608

OPEN ENDED LAB-II

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validatingthe hypothesis. The students shall submit a project report and appear for viva-voce.

CORE

CHE 10701

INORGANIC CHEMSITRY-III

(CONCEPTS AND DEVELOPMENTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitivelevel**
C.O. 1: Identify the structure-activity relationship of simple molecules based ontheir qualitative molecular orbitals.	Analyse
C.O. 2: Predict the stability and topology of different polyhedral boranes andrelated compounds.	Analyse
C.O. 3: Assess the strength of various acids and bases and their reactivity.	Analyse
C.O. 4: Explain behavior of different non-aqueous solvent systems towards different reactions.	Apply
C.O. 5: Interpret the structure and properties of compounds of sulfur, nitrogen,phosphorous and group 14 elements.	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					
C.O. 5	x	x			x					

UNIT – 1 **(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, $B_3N_3H_6$, S_3N_3, $N_3P_3Cl_6$, Si_2H_2. Importance of frontiermolecular orbitals, Shape, energy and reactivity of molecules.

UNIT – 2 **(10 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 approachto 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; Boron halides, boron heterocycles, borazine.

UNIT – 3 **(10 hrs)**

Relative strength of acids, Pauling rules, Lux-Flood concept, 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.

UNIT – 4 **(8 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.

UNIT – 5 **(10 hrs)**

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. Transition metaldichalcogenides, MoS_2. Structure, bonding and reactivity of 2D and 3D Carbon, Silicon and Germanium materials. Carbon nitrides, fullerenes, carbon nano tubes (CNT's) and graphenes.

Recommended Text Books:

1. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed., Pearson, 2014.
2. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of Structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
3. F. A. Cotton, G. Wilkinson, C. A, Murillo, M. Bochmann, Advanced Inorganic Chemistry, 6th ed., Wiley-Interscience: New York, 1999.
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., Wiley, 1994.
6. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd ed., Butterworth-Heinemann, 1997.
7. C.E. Housecroft, A.G. Sharpe, Inorganic Chemistry, 5th ed., Pearson, 2018.
8. E. Wiberg, A.F. Holleman, N. Wiberg, Inorganic Chemistry, Academic Press,2001.
9. A. V. Kolobov, J. Tominaga, Two-Dimensional Transition Metal Dichalcogenides, Springer, 2016.
10. Yu-Chuan Lin, Properties of Synthetic Two-dimensional Materials and Heterostructures, Springer, 2018.
11. Changzheng Wu, Xiaojun Wu, et al, Inorganic Two-dimensional Nanomaterials: Fundamental Understanding, Characterization and Energy Applications, RSC, 2017
12. D.R. MacFarlane, Mega Kar, J.M. Pringle, Fundamentals of ionic liquids, Wiley- VCH, 2017.
13. Yizhak Marcus, Deep Eutectic Solvents, Springer, 2019.
14. J.M. DeSimone and W. Tumas, Green Chemistry Using Liquid and Supercritical Carbon dioxide, D.U.P, 2003.
15. F. M. Kerton , R. Marriott , teal., Alternative Solvents For Green Chemistry, 2nd ed, RSC, 2013.

CORE

CHE 10702

ORGANIC CHEMISTRY -I

(REACTIVITY AND MECHANISMS)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitivelevel**
C.O.1: Review different bonding models with emphasis on understandingthree dimensional structures of molecules.	Analyse
C.O.2: Study Qualitative Molecular Orbital Theory and group orbital conceptsto sketch MO's of common organic structures, functional groups etc.	Evaluate
C.O.3: Apply the concepts of Frontier orbital theory in the study of ionic,radical and pericyclic reactions.	Analyse
C.O.4: Interpret structure and stability of reactive intermediates.	Evaluate
C.O.5: Apply methods and techniques to study mechanisms of organicreactions.	Apply
C.O.6: Predict the reactivity of an organic compound from its structure andbased on the reaction conditions.	Evaluate
C.O.7: Propose a reasonable mechanism for a given organic reaction.	Evaluate
C.O.8: Predict the products in a particular reaction considering thestereochemical aspect.	Evaluate
C.O.9: Illustrate the mechanistic pathway of different rearrangement reactionsand identify the products.	Analyse
C.O.10: Identify the mechanism and the product in a given reaction underphotochemical condition.	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		
C.O.5	x	x						x		
C.O.6	x	x			x			x		
C.O.7	x	x			x			x		
C.O.8	x	x			x			x		
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		

UNIT – 1 **(10 hrs)**

Study of Structure and Models of bonding: VB and MO models of bonding, Structure and Stability of Reactive intermediates: Carbocations, Carbanions, Carbenes, Nitrenes, and Radicals. Bonding Weaker than Covalent Bonds. Solventand solution properties, solvent scales. Acid – Base properties in non-aqueous systems, acidity scales, 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.

UNIT – 2 **(10 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

UNIT – 3 **(14 hrs)**

Substitutions on Aliphatic carbon – saturated and unsaturated systems – Mechanism of nucleophilic substitution – SN2, SN1 – 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 involvingaromatic substitution.

UNIT – 4 **(16 hrs)**

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.

Rearrangements involving electron deficient carbon and nitrogen. Mechanismof the following 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, Seyferth-Gilbert homologation, Grubbs catalysts and olefinmetathesis.

UNIT – 5 **(14 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 cycloaddtions, Electrocyclic reactions, Sigmatropic rearrangements and Chelotropic reactions.

Pericyclic Reactions in Organic Synthesis: Stereochemistry and Regiochemistryof Cycloaddtions. 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.

1,3-dipolar cycloaddition reactions, Photochromism and thermochromism, Pericyclic reactions in Organic synthesis – case studies.

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-pimethane rearrangement, Barton reaction, photochemistry of olefins, arenes, cyclohexadienones; photoreduction
and photo-oxygenation.

Recommended Text Books:

1. J. March, Advanced Organic Chemistry: Reactions, Mechanisms, and Structure,7th ed., Wiley, 2013.
2. T. H. Lowry, K. S. Richardson, Mechanism and Theory in Organic Chemistry,3rd ed., Benjamin-Cummings Publishing Company, 1997.
3. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5thed., Springer, 2008.
4. E. V. Anslyn, D. A. Dougherty, Modern Physical Organic Chemistry. UniversityScience Books, 2006.
5. F. A. Carroll, Perspectives on structure and mechanism in organic chemistry,Wiley, 2011.
6. N. S. Issacs, Physical Organic Chemistry, 2nd Edition, Prentice Hall, 1995.
7. A. Pross, Theoretical and Physical Principles of Organic Chemistry, 1st ed.,Wiley, 1995.
8. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed.,University Press, 2012.
9. Flemming: Molecular orbitals and organic chemical reactions, student ed.,Wiley, 2009.
10. J. McMurry, Organic Chemistry, 5th ed., Brooks/Cole, 2000.
11. R. Bruckner, Advanced organic chemistry: Reaction Mechanisms. AcademicPress, 2001.
12. P. Sykes, Guidebook to Mechanism in Organic Chemistry, 6th ed., Prentice Hall,1986.
13. N. J. Turro, Modern Molecular Photochemistry, University Science Books,1996.
14. N. J. Turro, J. C. Scaiano, V. Ramamurthy, Modern Molecular Photochemistryof Organic Molecules, 1st ed., University Science Books, 2010.

CORE

CHE 10703

THEORETICAL CHEMISTRY-I

(QUANTUM CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitivelevel**
C.O.1: Account for the basic principles and concepts of quantum mechanics.	Analyse
C.O.2: Apply the postulates of quantum mechanics to simple systems of chemical interest, such as the particle-in-a-box, harmonic oscillator, rigid rotor, and hydrogenic atoms.	Apply
C.O.3: Derive the variational principle, use it to calculate properties for simplesystems of chemical interest.	Analyse
C.O.4: Use perturbation theory to calculate properties for simple systems ofchemical interest.	Analyse
C.O.5: Define and explain the Hartree-Fock self-consistent field method.	Understand

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x						x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		
C.O. 5	x	x						x		

UNIT – 1 **(10 hrs)**

Wave-particle duality, uncertainty principle, postulates of quantum mechanics, Schrödinger equation, Time dependent and time independent Schrodinger wave equation. Its application on some model systems viz., free particle, particle in one, two and three-dimensional box (rectangular and cubical), separation of variables, concept of degeneracy, introduction to quantum mechanical tunneling.

UNIT – 2 **(10 hrs)**

Vibrational motion, Harmonic oscillator, Method of power series, Hermite equation and Hermite Polynomials, Recursion formula, wave function and energy.

Rigid rotator, Wave function in spherical polar coordinates, Planar rotator, phi equation, theta equation and solutions Lagendre equation and Lagendre polynomials, Spherical harmonics, Angular momentum operator L^2 and L_z, Spacequantization.

UNIT – 3 **(10 hrs)**

H atom, separation into three equations and solutions, Laguerre equation and Laguerre polynomials wave equation and energy of H like systems, quantum numbers and their importance, Radial wave function and radial distribution functions, angular wave function, Shapes of s, p, d and f atomic orbitals.

Postulate of electron spin-orbital and spin functions. Zeeman effect.

UNIT – 4 **(12 hrs)**

Many electron atoms. Approximate methods in quantum mechanics: The variation theorem, linear variation principle and perturbation theory (first order and non-degenerate), application of variation method and perturbation theory to the Helium atom, antisymmetry, Pauli exclusion principle, Slatter determinantal wave functions. Electron spin.

UNIT – 5 **(6 hrs)**

Hartree-Fock Self Consistent Field method, The Coulomb and Exchange Operators, The Fock Operator, Koopmans' theorem, Brillouin's theorem, The Roothaan Equations, Slater's treatment of complex atoms, Slater orbitals. Pauli principle, Slater determinant and wave function.

Recommended Text Books:

1. D. A. McQuarrie, Quantum Chemistry, 3rd ed., Univ. Sci. Books, Mill Valley, California, 1983.
2. I. N. Levine, Quantum Chemistry, 6th ed., Pearson Education, London, 2008.
3. P. W. Atkins, R.S Friedman, Molecular Quantum Mechanics, 5th ed., OUP, Oxford, 2012.
4. J. P. Lowe, Quantum Chemistry 3rd ed., Academic Press, New York, 2008.
5. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Book ed., Mc.Graw-Hill, New York, 1982.
6. P.W. Atkins, Physical Chemistry, 8th ed., Wiley, New York, 2006.
7. R. K. Prasad, Quantum Chemistry, 3rd ed., New Age International, 2006.
8. D. J. Griffiths, Introduction to Quantum Mechanics, 2nd ed., 2004.
9. J. J. Sakurai, Modern Quantum Mechanics, 2nd ed., 2010.

CORE

CHE 10704

THEORETICAL CHEMSITRY-II

(GROUP THEORY AND SPECTROSCOPY)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitivelevel**
C.O. 1: Analyze the symmetry of any given molecule and assign the pointgroup	Analyze
C.O.2: Apply the principles of symmetry and group theory in structure,bonding and spectral characteristics of molecules	Apply
C.O.3: Explain the factors affecting the intensity and broadening of lines inspectra and methods to enhance the sensitivity	Understand
C.O.4: Explain the principles of rotational, vibrational, Raman, electronic, fluorescence and NMR spectroscopy	Understand
C.O.5: Solve problems based on rotational, vibrational, Raman electronic,fluorescence and NMR spectroscopy	Apply
C.O.6: Apply various theoretical aspects to various spectroscopic techniquesfor prediction of different spectroscopic observations	Analyze

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x	x	x		x	
C.O.4	x	x			x	x	x		x	
C.O. 5	x	x			x	x	x		x	
C.O. 6	x	x			x	x	x		x	

UNIT – 1 **(18 hrs)**

Matrix representation of symmetry operations, similarity transformation and classes, Symmetry classification of molecules into point groups (Schoenfliessymbol)- Application of symmetry to predict polar and chiral compounds. 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.

UNIT – 2 **(12 hrs)**

Application of symmetry to predict polar and chiral compounds. Application of Group theory to Hybridization of atomic orbitals: Construction of hybrid orbitals for AB_3(planar), $AB_4(T_d)$, $AB_5(D_{3h})$ and $AB_6(O_h)$ 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 $PtCl_4^{2-}$. Molecular orbitals for tetrahedral and octahedral molecules.

UNIT – 3 **(12 hrs)**

Spectroscopy and its importance in chemistry. Link between spectroscopy and quantum chemistry, Energy levels in molecules, Born-Oppenheimer approximation,

Absorption and emission of radiation, Intensity and width of spectral lines, Beer lambert's law, Integrated absorption coefficient, Line width – natural line broadening, Doppler broadening, minimisation of line broadening, Induced and spontaneous transitions, correlation to the Einstein coefficients of absorption and emission, Basis of selection rules Fermi golden rule, lasers.

UNIT – 4 **(12 hrs)**

Rotational spectroscopy: Rotation of rigid bodies, moment of inertia, linear molecules, spherical, symmetric and asymmetric tops, Schrödinger equation ofa rigid rotator and brief discussion of its results, Quantization of rotational energy levels, selection rules, rotational spectra and line intensities, structure determination from rotational constants, isotopic effects.

Vibrational Motion: Schrödinger equation of a linear harmonic oscillator and brief discussion of its results, concept of zero-point energy. Quantization of vibrational energy levels. Selection rules, IR spectra of diatomic molecules. Structural information derived from vibrational spectra, dissociation energies, vibration-rotation transitions in diatomics, harmonic oscillator, anharmonicity, centrifugal distortion, Vibration of polyatomic molecules, normal modes, combination, difference and hot bands, Fermi Resonance, Group frequencies. Effect of hydrogen bonding (inter- and intramolecular) on vibrational frequencies.

Raman spectroscopy: Light scattering and Raman effect, classical and quantum models for scattering, Stokes and anti-Stokes lines; their intensity difference, polarizability, selection rules, group theoretical treatment of vibrations, Effect of nuclear spin, Vibrational Raman spectra, rule of mutual exclusion for centrosymmetric molecules, polarized and depolarized Raman lines, resonance Raman scattering.

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

UNIT – 5 **(10 hrs)**

Electronic Spectroscopy of molecules: Molecular orbitals and states, term symbols, selection rules, vibrational and rotational structures, Free Electron model, its application to electronic spectra of polyenes. Frank-Condon principle, electronic transitions, Beer Lambert's Law, dissociation and predissociation, photoelectron spectroscopy, dissociation and predissociation, calculation of heat of dissociation, Birge Sponer method, electronic spectroscopy of polyatomic molecules Singlet and triplet states, Jablonski diagram, fluorescence and phosphorescence, Solvent and environmental effects, Fluorescence quenching, energy transfer andelectron transfer, time domain lifetime measurements.

NMR: Expression for Hamiltonian/Energy - Zeeman interaction, torque exerted by a magnetic field on spins, equation, its solution and the physical picture of precession. Thermal equilibrium, Relaxation, chemical shift, shielding and deshielding, Karplus relationships, Bloch equations, the rotating frame, pulsed experiments, NOE, double irradiation, selective decoupling, double resonance, Polarisation transfer, Two-dimensional NMR, Solid state NMR, NQR, MRI.

Recommended Text 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 Introductionto Chemical Applications, 2nd ed., Wiley, 2013.
4. Robert L. Carter, Molecular Symmetry and Group Theory, Wiley, 2009.
5. G. M. Barrow, Introduction to Molecular Spectroscopy, McGraw Hill, New York, 1962.
6. C. N. Banwell, Fundamentals of Molecular Spectroscopy, 4th ed., Tata McGraw Hill, 1996.
7. A. E. Derome, Modern NMR Techniques for Chemical Research, Pergamon Press, 1987.
8. D. H. Williams, I. Flemming, Spectroscopic Methods in Organic Chemistry, 4th ed., McGraw-Hill, 1985.
9. H. Gunther, NMR Spectroscopy, 2nd ed., John Wiley, 2005.
10. N. B. Colthup, L. H. Daly, S. E. Wiberley, Introduction to Infrared and Raman Spectroscopy, 3rd ed., 1982.
11. R. A. Alberty, Physical Chemistry 8th ed., Wiley, New York, 1994.
12. P. W. Atkins, Physical Chemistry 8th ed., W. H. Freeman, New York, 2006.
13. I. N. Levine, Molecular Spectroscopy, John Wiley & Sons.
14. J. M. Hollas, Modern Spectroscopy, John Wiley & Sons.
15. P. F. Bernath, Spectra of Atoms and Molecules, III Edn, Oxford University Press.
16. J. L. McHale Molecular Spectroscopy, Pearson Education.
17. W. W. Parson, Modern Optical Spectroscopy, Springer-Verlag.
18. Jack D. Graybeal, Molecular Spectroscopy, Mc Graw Hill International Editions
19. M.H. Levitt, Spin Dynamics, II edn.Wiley
20. James Keeler, Understanding NMR spectroscopy, II edn. Wiley
21. Joseph R. Lakowicz, Principles of Fluorescene Spectroscopy, 3rd Ed., Plenum Press, 2010.

CORE/LAB

CHE 10705

ADVANCED CHEMICAL SYNTHESIS AND SEPARATION LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitivelevel**
C.O.1: Acquire knowledge on safe laboratory practices of handling laboratoryglassware, equipment and chemical reagents.	Knowledge
C.O.2: Plan and perform synthetic procedures, chromatographic separation andpurification of organic compounds.	Understand
C.O.3: Separate organic compounds from the organic binary mixture andidentify the functional group(s) present.	Analysis
C.O.4: Use software to Draw the structures and schemes of organic moleculesand reactions.	Apply
C.O.5: Use Chemical Abstracts, Scopus, Organic Synthesis collective volumeson web etc. to search, analyse and collect chemical information.	Apply
C.O.6: Identify the cations in a mixture of unknown salts.	Analyse
C.O.7: Estimate the amount of a given metal ion by complexometric andcerimetric reactions.	Analyse
C.O.8: Synthesise metal complexes and characterize them by variousphysicochemical methods.	Apply
C.O.9: Record and interpret electronic spectrum of different metal complexes.	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x				x		x	x	
C.O.2	x	x	x		x	x		x	x	
C.O.3	x	x		x		x		x	x	
C.O.4	x	x				x	x	x	x	
C.O.5	x	x			x	x		x	x	
C.O.1	x	x						x	x	
C.O.2	x	x		x				x	x	
C.O.3	x	x	x			x		x	x	
C.O.4	x	x				x	x	x	x	

UNIT – 1 **(48 hrs)**

Part I: General methods of separation and purification of Organic compounds such as 1) Solvent extraction 2) Thin layer chromatography and paper chromatography 3) column chromatography

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

Part III: Preparation of Organic compounds by multistep reactions, purification of products and characterisation using UV-Vis, FTIR and NMR.*

Part IV: Drawing the structures of organic molecules and reaction schemes by Proprietary and open source computer software. Use Chemical Abstracts, Scopus, Organic Synthesis collective volumes on web etc., to search, analyse and collect chemical information.

***Progress of the reactions should be followed by spectroscopic and chromatographic methods (UV-Vis, TLC, GC, HPLC, etc)**

UNIT – 2 **(48 hrs)**

Reactions of titanium, vanadium, chromium, manganese, iron, cobalt, nickel and copper ions. Reactions of some less common metal ions (Tl, W, Mo, V, Zr, Th, U). The spot test technique for metal ions. Semimicro qualitative analysis of common and rare cations in a mixture.

Estimation of metal ions by complexometric and cerimetric titrations. Estimation of Mg, Ca, Mn, hardness of water.

Synthesis of inorganic complexes and their characterization by various physicochemical methods, such as IR, UV, Visible, NMR, magnetic susceptibility etc. Selection can be made from the following or any other complexes for which references are available in the literature.

Tris(oxalato)manganese(III)

Tetrapyridinesilver(II)peroxidisulphateTris(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) sulphatePhenyl

lithium

Tetraphenyl lead Ferrocene

Phosphonitrilic chloride

Anhydrous copper(II) nitrate

Interpretation of its electronic spectrum and calculation of Dq values. Determination of crystal field splitting energy for certain ligands and construction of a part of the spectrochemical series.

Recommended Text Books:

1. 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.

2. D. L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Organic laboratory Techniques, 3rd ed., Saunders Golden Sunburst Series.

3. L. W. Harwood, C. J. Moody, Experimental Organic Chemistry-Principles Blackwell Science Publications.

4. G. Pass, H. Sutcliffe. Practical Inorganic Chemistry 2nd ed., Chapman & Hill. 1974.

5. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand, 1972.

CORE/LAB

CHE 10706

OPEN ENDED LAB-III

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validatingthe hypothesis. The students shall submit a project progress report.

ELECTIVE

CHE 10707

SUPRAMOLECULAR CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Explain the structural features of any given supramolecular system	Analyze
C.O.2: Analyze the type of possible interactions in any given host guest assembly	Analyze
C.O.3: Predict the photochemical and Photophysical behavior in constrained media	Analyze
C.O.4: Analyze the change in electronic structure of the supramolecular systems based on the interaction with the host	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x									
C.O.2	x	x								
C.O.3		x			x					
C.O.4					x		x			

UNIT – 1 **(10 hrs)**

Structure, Preparation and Properties of: crown ethers, cryptates, cryptands, carcerands, calixarenes, cyclodextrins, fullerenes, dendrimers, rotaxanes,cucurbiturils, COF, MOF.

UNIT – 2 **(10 hrs)**

Noncovalent Interactions –Hydrogen bonding, π Effects, dipole interactions, Induced dipole interactions, Hydrophobic interactions. Solvent Effects, Thermodynamics of binding phenomena.

UNIT – 3 **(10 hrs)**

Molecular Recognition – Host guest interactions, Complementarity and Reorganization, large ion pairing component, hydrophobic component, hydrogen bond, π-component. Complex Architectures – Self-assembly, coordination, hydrogen bonding.

UNIT – 4 **(10 hrs)**

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

UNIT – 5 **(8 hrs)**

Applications – photocatalysis, water splitting, solar cell, CO2 reduction, drug delivery, sensors, gas separation and storage.

Recommended Text 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, UniversityPress, 2006.
4. P. Klan and J. Wirz, Photochemistry of Organic Compounds
5. Modern Molecular Photochemistry of Organic Molecules, Nicholas J. Turro, V. Ramamurthy, J.C. Scaiano
6. Christian S. Diercks, Markus J. Kalmutzki, and Omar M. Yaghi, Introduction to Chemistry: Metal-Organic Frameworks and Covalent Organic Frameworks, Wiley, 2019.
7. Shengqian Ma, Jason A Perman, Elaboration and Applications of Metal-organic Frame works, WorldPress, 2018.

ELECTIVE

CHE 10708

GREEN CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Apply the concepts of green chemistry for a given chemical process	Analyze
C.O.2: Describe the various green materials which can be used as alternatives	Understand
C.O.3: Describe the various green technologies which can be used as alternatives	Understand

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x		x							
C.O.2	x		x							x
C.O.3	x		x							x

UNIT – 1 **(10 hrs)**

Green Chemistry and industry, waste minimization, E factor and atom economy, Reduction of-material use, energy, risk and hazards. Sustainable use of- chemical feedstocks, water, energy. LCA methodology, Renewables as Chemical Feedstocks and Biocatalysis, Process Intensification for Green Chemistry.

UNIT – 2 **(10 hrs)**

Catalysis in green chemistry – Homogenous catalysis , Heterogeneous catalysis, metal catalysts, metal oxide catalyst, metal complexes, Solid Acid Catalysts - Concepts and applications, Zeolite, Heteropolyacid, Ion-exchange resins as solid acid catalysts, Kvaerner Process, Nafion /silica nanocomposites, Haldor–Topsoe alkylation process to high-octane fuels. Micelle - templated Silica as Catalysts inGreen Chemistry -Synthesis of micelle templated materials, Catalytic Applications - Oxidation catalysis, Base catalysis, Enantioselective catalysis.

UNIT – 3 **(10 hrs)**

Phase-transfer Catalysis(PTC) - Classical PTC Reactions, Nucleophilic aliphatic and aromatic Substitutions, Phase-transfer catalysis elimination and isomerisation reactions, Base-promoted alkylation and arylation, Inverse PTC, Phase-transfer Catalysis in Polymerisation, Applications of PTC in Analytical Chemistry. Biocatalysis - antibody catalysts, Enzyme Catalysts, Biomimetic catalysts, Chemical Production by Biocatalysis, Bulk chemicals, Pharmaceuticals, Flavour and fragrance compounds, Carbohydrates, Polymers, Biocatalysis in supercritical CO_2, Biocatalysis in waste treatment.

UNIT – 4 **(10 hrs)**

Specific green technologies - hydrogen peroxide in waste minimization, waste minimization in pharmaceutical process development, supercritical carbondioxide as an environmentally benign reaction medium for chemical synthesis, reduction of volatile organic compound emission during spray painting. Extraction of natural product with super-heated water, Synthesis at organic – water interface, Envirocats, applications of microwaves for environmentally benign organic chemistry, Sonochemistry – Concept, application in chemicalsynthesis.

UNIT – 5 **(8 hrs)**

Photochemistry - Photons as Clean Reagents, Reduced usage of reagents, Lower reaction temperatures, Control of selectivity, Photochemical reactions for industry, General Problems with Photochemical Processes, Specialized photochemical reactors and process technology, Photochemical reactors, Light sources, Artificial Photosynthesis for small molecule conversions. Green Nanoscience - Photocatalysis by Nanostructured TiO_2-based Semiconductors, Formation of Nanoparticles Assisted by Ionic Liquids, Nanoencapsulation for Process Intensification, Nanophase Inorganic Materials, Nanomaterials from Biobased Amphiphiles.

Recommended Text Books:

1. Paul T. Anastas and John C. Warner, Green Chemistry: Theory and Practice,Oxford University Press, 1998.
2. J. Clark, D. Mcquarrie, Hand Book of green Chemistry and technology,Blackwell science, 2002.
3. Mike Lancaster, Green Chemistry: An Introductory Text, RSC, 2007.
4. P. T. Anastas, T. C. Williamsons, Green Chemistry – Designing Chemistry forthe Environment, ACS, 1994.
5. V. K. Ahluwalia, M. Kidwai, New Trends in Green Chemistry, 2nd edition, Anamaya Publishers, 2006.
6. V. K. Ahluwalia, Green Chemistry, Narosa Publishing House, 2011.
7. Alvise Perosa, Maurizio Selva, Handbook of Green Chemistry- Volume 8-Green Nanoscience, Wiley-VCH, 2012.

ELECTIVE

CHE 10709

POLYMER CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Recognise the concept of macromolecules and describe the classification, synthesis and process technologies involved in common polymers.	Understand
C.O.2: Analyse the kinetics and mechanism involved in different types of polymerization	Analyse
C.O.3: Apply the concepts of stereochemical aspects and analyse the conformation and configuration of polymers	Analyse

C.O.4: Apply different characterisation techniques to identify polymers.	Apply
C.O.5: Explain the synthesis, structure and applications of industrial polymers.	Understand

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x		x						x	
C.O.2					x					
C.O.3	x	x							x	x
C.O.4						x	x			
C.O.5						x	x			

UNIT – 1 **(10 hrs)**

History of Polymer Science. Concept of macromolecules, Principle of duality, Integration of molecular character and material character. Molecular design, synthesis and process technologies. Nomenclature and Classification. Raw Material sources of polymers. Natural gas, coal and petroleum. Monomers and polymers derived from natural gas. Petroleum and petrochemicals. Monomers and polymers derived from ethylene and propylene. Monomers and polymers derived from C4 and C5 Systems and BTX fraction. Acetylene as a source of monomers.

UNIT – 2 **(10 hrs)**

Polymerization processes. 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. The copolymerization equation, Q-e scheme, Gelation and Crosslinking. Copolymer composition drift. Polymerization techniques. Bulk Solution, melt, suspension, emulsion and dispersion techniques.

UNIT – 3 **(10 hrs)**

Polymer Stereochemistry. Organizational features of polymer chains. Configuration and conformation, Tacticity, Repeating units with more than one asymmetric center. Chiral polymers – main chain and side chain. Stereoregular polymers. Manipulation of polymerization processes. Zeigler-Natta and Kaminsky routes. Coordination polymerization. Metallocene and Metal oxide catalysts.

UNIT – 4 **(10 hrs)**

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

UNIT – 5 **(8 hrs)**

Industrial polymers. Synthesis, Structure and applications. Polyethylene, polypropylene, polystyrene. PVC, PVA, PAN, PA. Poly(vinyl carbazole), poly(vinyl imidazole). PMMA and related polymers. Flourine containing polymers. Reaction polymers. Polyamides, polyesters. Epoxides, polyurethanes, polycarbonates, phenolics, PEEK, Silicone polymers. Reactions of polymers. Polymers as aids in Organic Synthesis. Polymeric Reagents, Catalysts, Substrates, Liquid Crystalline polymers. Main chain and side chain liquid crystalline polymers.

Recommended Text Books:

1. Billmayer, F.W. Textbook of Polymer Science. 3rd Ed., Wiley. N.Y.1991.
2. Cowie, J.M.G. Polymers: Physics and Chemistry of Modern Materials. Blackie. London,1992.
3. Young, R.J. Principles of Polymer Science, 3rd Ed., Chapman and Hall. N.Y.1991.
4. Flory, P.J. A Text Book of Polymer Science. Cornell University Press. Ithacka, 1953.
5. Ullrich, F. Industrial Polymers, Kluwer, N.Y.1993.
6. Elias, H.G. Macromolecules, Vol. I & II, Academic, N.Y.1991.
7. Brydson, J.A. Polymer chemistry of Plastics and Rubbers, ILIFFE Books Ltd., London,1966

MOOC ELECTIVE

CHE 10710

BONDS AND BANDS IN SOLIDS

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe the theoretical aspects of solid state structure	Understand
C.O.2: Correlate the structural aspects to electronic properties	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x								
C.O.2	x	x								

UNIT – 1 **(6 hrs)**

One-electron Hamiltonian after B.O and SCF approx., Bonding in Hn System,n=2,3….N

UNIT – 2 **(6 hrs)**

Bloch's theorem, Energy bands, Metal, Insulator, Semi-conductors; Brillouin Zones,Different Schemes, Density of States, Extension to p-orbitals, square lattices etc

UNIT – 3 **(6 hrs)**

Peiperl's instability, Nearly Free Electron Model, Fermi Surface, Density of States, Effective Mass etc.,, Failures of MO and Band Theories, Beyond energy band , Interacting electron models and Kinetic exchange

UNIT – 4 **(6 hrs)**

Energy levels in interacting models, Excitons; Lattice, vibrations, Acoustic modes, optic modes etc.,

UNIT – 5 **(8 hrs)**

Phonon Photon interaction, thermal properties of insulators

Recommended Text Books:

1. C. Kittel, "Introduction to Solid State Physics"
2. J. M. Ziman, "Principles of the Theory of Solids"
3. N.W. Ashcroft and N.D. Mermin, "Solid State Physics"

AUDIT

CHE 10711

PROFESSIONAL AND CAREER DEVELOPMENT IN CHEMISTRY

Credit 0 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Skills on subject specific pedagogy, soft skills, ICT tools, research proposal writing, finding scholarships and software for chemistry	Create

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1									x	x

UNIT – 1 **(32 hrs)**

Soft Skills – Powerpoint, Word, Exel, Reference management software- Mendeley, Origin,

Veusz, Research Proposal Writing – Literature review, Components of proposals, ICT – Google Classroom, Moodle, Class Recording, Teach Infinity, OBS, edmondo, QUIZZ Quiz, Document scanner., Subject specific pedagogy – Molecular model kit, ChemDraw, ChemSketch, Finding International Scholarships- MEXT, DAAD, EURAXESS, J-Rec, Funding through embassy
Lab safety, research ethics, research methodology.

Recommended Text Books:

1. John M. Swales & Christine B. Feak, Academic Writing for Graduate Students3rd Edition, Michigan Publishing, 2012.
2. Stephen Bailey, Academic Writing, A Handbook for International Student, 5thEdition, Routledge, Taylor&Francis, 2018.

CORE

CHE 10801

Inorganic Chemistry – IV

(CHEMISTRY OF d- AND f-BLOCK ELEMENTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitivelevel**
C.O.1: Describe and explain the structure, bonding and magnetism in metal complexes using crystal field theory.	Analyse
C.O.2: Describe various metal-ligand interactions in terms of sigma- and pi-bonding.	Analyse
C.O.3: Identify various d-d transitions and interpret the electronic spectra of any given transition metal complex.	Evaluate
C.O.4: Interpret the ESR spectra of any given transition metal complex.	Evaluate
C.O.5: Explain the stability of metal complexes, their reactivity, and the mechanisms of ligand substitution and redox reactions.	Evaluate
C.O.6: Interpret the Mossbauer spectra of iron complexes.	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x						x		
C.O.2	x	x			x			x		
C.O.3	x	x				x		x		
C.O.4	x	x				x		x		
C.O.5	x	x			x			x		
C.O.6	x	x				x		x		

UNIT – 1 **(6 hrs)**

Crystal-field theory, d-orbital splitting in octahedral, tetrahedral, square planar, trigonal bipyramidal, trigonal planar and linear geometries, crystal fieldstabilization energy, effect of pairing energy.

Molecular Orbital Theory: construction of molecular orbital diagrams using group theory, qualitative MO diagrams for octahedral, tetrahedral and square planar complexes, effect of π-bonding, experimental evidence for π-bonding, spectrochemical series.

UNIT – 2 **(10 hrs)**

Microstates, Atomic term symbols Free ion terms for dn configuration, Splitting of terms in octahedral and tetrahedral octahedral fields, Correlation diagram for d^2 configuration in octahedral geometry, d-d transitions, Selection rules for electronic transitions.

Orgel diagram – splittings for d^1, d^9, high spin d^4, d^6, splittings for high spin d^2, d^3, d^8 and d^7 Calculation of Dq, B and β

Tanabe Sugano diagrams – splittings for low spin d^n 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.

UNIT – 3 **(6 hrs)**

Magnetism: brief review of different types of magnetic behaviours, spin-orbit coupling, quenching of orbital angular moments in crystal field, spin-only formula, correlation of μ_s and μ_{eff} values, magnetic moments of T terms and A, E terms, temperature independence paramagnetism, magnetic properties oflanthanides and actinides.

UNIT – 4 **(12 hrs)**

Electronic paramagnetic resonance spectroscopy: Electronic Zeeman effect, Zeeman Hamiltonian and EPR transition energy. 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 spectroscopy- Principles and applications to coordination compounds.

UNIT – 5 **(14 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

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

4. J. W. Steed, J. L. Atwood, Supramolecular Chemistry, 2nd ed., John Wiley & SonsLtd., 2009.
5. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3rd ed.,ELBS, 1999.
6. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd ed., John Wiley and Sons, 1994.
7. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd ed., BH, 1997.
8. R. S.Drago, Physical Methods for Chemists, 2nd ed., Saunders CollegePublishing, 1992.
9. C. E. Housecroft, A. G. Sharpe, Inorganic Chemistry, 5th ed., Pearson, 2018.
10. W. L. Jolly, Modern Inorganic Chemistry, 2nd ed., McGraw-Hill, New York, 1991.
11. Elements of Chemical Thermodynamics, Addison Wesley, 2nd Edn, 2013.

CORE

CHE 10802

ORGANIC CHEMISTRY -II

(REACTIONS, REAGENTS AND SYNTHESIS)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Interpret the differences in reactivity of various reducing and oxidizing agents with mechanistic illustrations.	Apply
C.O.2: Analyse the reagents and conditions for the synthesis of specific target molecules.	Analyse
C.O.3: Describe strategies for the stereospecific/stereo selective organic transformations towards chiral target molecules.	Apply
C.O.4: Construct a synthetic pathway for simple to complex organic molecules by retrosynthetic approach.	Apply

	Programme Outcomes

Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x									
C.O.2			x					x		
C.O.3			x					x		
C.O.4			x					x		

UNIT – 1 **(14 hrs)**

Reagents for oxidation and reduction: Chromium reagents, activated DMSO, osmium tetroxide, selenium dioxide, singlet oxygen, peracids, hydrogenperoxide, periodic acid, lead tetraacetate, ozonolysis, Woodward and Prevost hydroxylation, Wacker process, Oppenauer oxidation, Sharpless, Shi andJacobsen 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..

(12 hrs)

UNIT – 2

Synthetic applications of organometallic and organo-nonmetallic reagents: Hydorboration 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.

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, Biginelli reaction. Click reaction.

UNIT – 3 **(12 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.
Reaction with phosphorous and sulfurylides.

UNIT – 4 **(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.

UNIT – 5 **(14 hrs)**

Synthesis planning and analysis: Convergent, divergent and parallel synthesis. Protecting groups- protection and deprotection of hydroxyl, carboxylic acids, carbonyls in aldehydes and ketones, amines, alkenes and alkynes. Chemo- & regioselective protection and deprotection. Functional group equivalents, reversal of reactivity (Umpolung). Disconnection approach-introduction to retrosynthesis, basic principles, synthons, and synthetic equivalents. Monofunctional and bifunctional disconnection, One group C-X and two group C-X disconnections, one group C-C and two group C-C disconnections. Retrosynthesis of longifoline, Corey lactone, Djerassi - Prelog lactone and D-luciferin.

Recommended Text 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), 5thed., Springer, 2008.
4. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed.,Oxford University Press, 2012.
5. P. S. Kalsi, Stereochemistry, Conformation and Mechanism, 9th ed., New Age Publications, 2017.
6. T. Tsuji, Transition Metal Reagents and Catalysts: Innovations in OrganicSynthesis, John Wiley & Sons, 2000.
7. S. Warren, Organic Synthesis: The Disconnection Approach, 2nd ed., JohnWiley, 2008.
8. E. Robert, Gawley, J. Aube, Principles of Asymmetric Synthesis, 2nd ed.,Elsevier, 2012.
9. G. L. D. Krupadanam, Fundamentals of Asymmetric Synthesis, 1st ed., CRCpress, 2014.
10. T.W. Greene, P. G. M. Wuts, Protecting Groups in Organic Synthesis, 2nd ed.,John Wiley, 1991.
11. H. R. Crabtree, The Organometallic Chemistry of the Transition Metals, 6th ed.,John Wiley & Sons, 2014.
12. S. D. Burke, R. L. Danheiser, Handbook of Reagents for Organic Synthesis,John

Wiley & Sons, 1999.

CORE

CHE 10803

ORGANIC CHEMISTRY -III

(SPECTROSCOPY OF ORGANIC COMPOUNDS)

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Identify structures of unknown organic compounds using hyphenated techniques and spectral library matching.	Apply
C.O.2: Identify structures of unknown organic compounds based on the data from UV-Vis, IR, Mass Spectrometry $_1$HNMR and $_{13}$CNMR spectroscopy.	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x						x	x	
C.O.2	x	x						x	x	

UNIT – 1 **(6 hrs)**

Study of Mass Spectrometry applied to organic molecular systems Elemental analysis, empirical formula, molecular formula, Molecular mass, nominal mass, Exact mass, Index of hydrogen eficiency.

The technique of Mass Spectrometry: Molecular ion, ion production methods (EI). Soft ionization methods: FAB, CA, MALDI, PD, Field desorption electrospray ionization, HRMS and formula mass, LC-MS, GC-MS. MS- MS Mass spectra of chemical classes and its correlation with structure: Fragmentation patterns, nitrogen and ring rules, Rule of thirteen, McLafferty rearrangement.

UNIT – 2 **(6 hrs)**

Study of Ultraviolet-Visible Absorption and Emission and Chirooptical Spectroscopy applied to organic molecular systems Energy levels and selection rules, Woodward-Fieser and Fieser-Kuhn rules, estimation of λmax of substituted aromatic ketones, aldehydes and acids. Spectralcorrelation with structure: Influence of substituents, conjugation, Intramolecular Charge transfer, Solvent effect Fluorescence Spectroscopy. Excitation and Emission Spectra. Fluorescence Quantum Yield and Lifetime. Spectral correlation with structure: Influence of substituents, ring size, strain and conjugation, Intramolecular Charge transfer, Intramolecular proton transfer, Solvent effect Chirooptical Spectroscopy: Introduction and applications of ORD, CD, Octant rule, axial haloketone rule, Cotton effect.

UNIT – 3 **(6 hrs)**

Study of Infrared Spectroscopy applied to organic molecular systemsFundamental vibrations, overtones, Fermi Resonance, Hot bands, combination bands Spectral correlation with structure: Characteristic regions of the spectrum. Influence of substituents, ring size, hydrogen bonding, vibrational coupling, hybridization and field effect on frequency. IR spectra of chemical classes including amino acids and its correlation with structure Study of NMR spectroscopy applied to organic molecular systems.

UNIT – 4 **(10 hrs)**

The NMR instrumentation and Experiment: Magnetic nuclei with special reference to 1H and 13C nuclei. Chemical shift and shielding/deshielding, relaxation processes, chemical and magnetic non-equivalence, local diamagnetic shielding and magnetic anisotropy. Proton and 13C NMR scales, characteristics of 13C as a nucleus.

Spin-spin splitting, AX, AX2, AX3, A2X3, AB, ABC, AMX type coupling, First order and non-first order spectra, Pascal's triangle, coupling constant, mechanism of coupling, Karplus curve, quadrupole broadening and decoupling, diastereomeric protons, virtual coupling, long range coupling effects, NOE, coupling with other nuclei.

Simplification non-first order spectra to first order spectra, shift reagents- mechanism of action, spin decoupling and double resonance, Chemical shifts and homonuclear/heteronuclear couplings, the basis of heteronuclear decoupling. Polarization transfer. Selective Population Inversion (qualitative description only), DEPT, sensitivity enhancement and spectral editing. 2D NMR and COSY, HMQC, HMBC.

UNIT – 5 **(4 hrs)**

Identification of structures of unknown organic compounds using hyphenatedtechniques and

Spectral library matching.

Identification of structures of unknown organic compounds based on the datafrom UV-Vis, IR, Mass, 1HNMR and 13CNMR spectroscopy.

Recommended Text Books:

1. D. L. Pavia, G. M. Lampman, G. S. Kriz, J. R. Vyvyan, Introduction to Spectroscopy: A Guide for Students of Organic Chemistry, Indian ed., Brooks/Cole Cengage Learning, 2007.
2. Atta-Ur-Rahman, M. I. Choudhary, Solving Problems with NMR Specroscopy, Academic Press, New York, 1996.
3. L. D. Field; S. Sternhell, J. R. Kalman; Organic Structures from Spectra, 4th ed., Wiley 2008.
4. R. S. Drago, Physical Methods for Chemist, Saunders,1992.
5. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4thed., McGrawHill, 1994.
6. D. F. Taber, Organic Spectroscopic Structure Determination, A Problem Based Learning Approach, Oxford University Press, 2009.
7. R. M. Silverstein, G. C. Bassler, T. C. Morril, Spectroscopic Identification of Organic Compounds, John Wiley, 1991.
8. D. H. Williams, I. Fleming, Spectroscopic Methods in Organic Chemistry, Tata McGraw Hill, 1988.
9. W. Kemp, Organic Spectroscopy, 2nd ed., ELBS-Macmillan, 1987.
10. F. Bernath, Spectra of Atoms and Molecules, 2nd ed., Oxford University Press, 2005.
11. E. B. Wilson, Jr., J. C. Decius, P. C. Cross, Molecular Vibrations: The Theory of Infrared and Raman Spectra, Dover Publications, 1980.
12. A. Weil, J. R. Bolton, Electron Paramagnetic Resonance: Elementary Theoryand Practical Applications, 2nd ed., Wiley Interscience, John Wiley & Sons, Inc.,2007.
13. C. P. Slichter, Principles of Magnetic Resonance, 3rd ed., Springer-Verlag, 1990.
14. H. Gunther, NMR Sprectroscopy: Basic Principles, Concepts and Applications in Chemistry, 3rd ed., Wiley- VCH, 2013.
15. Spectral data bases (RIO DB of AIST, for example).

CORE

CHE 10804

PHYSICAL CHEMISTRY- III

(STATISTICAL AND NON-EQUILIBRIUM THERMODYNAMICS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Explain the different types of statistics and calculate the thermodynamic probability of any given thermodynamic system.	Analyse
C.O. 2: Calculate the partition function and thermodynamic properties from spectroscopic data.	Apply
C.O. 3: Apply the principles of statistical thermodynamics to ideal gases, solids and metals.	Apply
C.O. 4: Explain the basics of transport phenomena's viz., Osmosis, biological motors and electro kinetic effects.	Understand
C.O. 5: Derive expression for entropy production for physical and chemical processes	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					

C.O.4	x	x			x					
C.O.5	x	x			x					

UNIT – 1 **(8 hrs)**

Kinetic Theory of gases, Maxwell Distribution of velocity, Boltzmann distribution, Types of molecular velocities- r.m.s, most probable and mean velocity, Molecular Collisions, Mean free path, Transport properties- Diffusion,effusion, Viscosity, Thermal conductivity.

Thermodynamic probability, microstate and macrostate, entropy and probability, most probable distribution, residual entropy and its calculation. Ensembles, Maxwell - Boltzmann statistics.

UNIT – 2 **(10 hrs)**

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, Anomalous heat capacity of H_2, Heat capacity of solids: Dulong - Petits law, Einstein's theory and its modification, Debye's theory of heat capacity of solids.

UNIT – 3 **(10 hrs)**

Quantum statistics, Bose - Einstein statistics, Fermi - Dirac statistics, Comparison of Maxell - Boltzman, Bose=- Einstein and Fermi - Dirac Statistics, Dilute Systems. Application of Bose - Einstein Statistics, Gas degeneration, Application to liquid helium, Bose Einstein Condensation. Application of Fermi -Dirac Statistics to electrons in metals, Extreme Gas Degeneration, Electron gas in metals and its contribution to pressure and heat capacity.

UNIT – 4 **(10 hrs)**

Partition function for systems of dependent particles, Configurational integral and configurational partition function. Imperfect gas, van der Waals equation and Virial equation of state, Evaluation of the first virial coefficient. Condensed state, Cluster integrals, Communal entropy.

UNIT – 5 **(10 hrs)**

Linear Non-equilibrium thermodynamics- General theory, Local entro pyproduction, 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 Text Books:

1. F.W. Sears, Introductions to Thermodynamics, Kinetic Theory of Gases and Statistical Mechanics, Addision Wesley Pub. Cambridge, 1998.
2. F.C. Andrews, Equilibrium to Statistical Mechanics, John Wiley, New York,2002.
3. L.K. Nash, Statistical Thermodynamics, Addison Wesley, New York, 1999.
4. P. W. Atkins, J. de Paula, Physical Chemistry 8th ed., 9th edn. Wiley, New York,2006
5. D. A. McQuarrie, Physical Chemistry- A Molecular Approach, South AsianEdn., 2008.
6. M. Dole, Introduction to Statistical Thermodynamics, Prentice Hall, London,1997.
7. J. Kestin, J.R. Dorfman, A Course in Statistical Thermodynamics, Academicpress, 1971.
8. D. A. McQuarrie, Statistical Thermodynamics, South Asian Edn., 2008.
9. I. Prigogine, Introduction to Thermodynamic Irreversible Processes, 3rd ed., Wiley Interscience, 1968.
10. S. R. de Groot, P. Mazur, Non-equilibrium Thermodynamics, Dover Publications, 2011.
11. G. Lebon, D. Jou, J. Casas, Understanding Non-equilibrium Thermodynamics, Springer. 2008.
12. S. Kjelstrup, D. Bedeaux, E. Johannessen, J. Gross, Non-Equilibrium Thermodynamics for Engineers: Second Edition, World Scientific Publishing Company, 2017.
13. D. Kondepudi and I. Prigogine, Modern Thermodynamics: From Heat Engines to Structures, Wiley, New York.

CORE

CHE 10805

THEORETICAL CHEMISTRY-III

(CHEMICAL BONDING AND COMPUTATIONAL CHEMISTRY)

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Explain the quantum mechanical nature of the chemical bond.	Understand
C.O.2: Account for the basic principles and concepts of molecular orbital theory and valence bond theory using quantum mechanical principles.	Apply
C.O.3: Describe quantum mechanically the chemical bonding of any given di- and tri- atomic molecules with molecular orbital theory and valence bond theory.	Analyze

C.O.4: Describe the main similarities and differences between theoretical approaches and identify advantages and disadvantages for modelling various chemical problems.	Apply
C.O.5: Use computational chemistry software to perform and interpret electronic structure calculations.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x						x		
C.O.2	x	x						x		
C.O.3	x	x						x		
C.O.4	x	x			x	x	x	x		
C.O. 5	x	x			x		x	x	x	

UNIT – 1 **(8 hrs)**

Chemical boning, Born Oppenheimer approximation, Valence bond method. Comparison of VB and MO method, LCAO approximation, calculation of energylevels from wave functions, application to diatomic molecules such as, H_2^+, H_2. 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

UNIT – 2 **(6 hrs)**

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.

UNIT – 3 **(6 hrs)**

Tools and philosophy of computational chemistry. potential energy surface - localminima, global minima, saddle point and transition states, geometry optimization-stationary points.

UNIT – 4 **(6 hrs)**

Basis sets, Slater and Gaussian functions, classification of basis sets - minimal, double zeta, triple zeta, split valence, polarization and diffuse basis sets, contracted basis sets, Pople style basis sets and their nomenclature, correlation consistent basis sets.

SCF methods, semiempirical, ab initio, electron correlations, post-Hartree-Fock methods and density functional theory.

UNIT – 5 **(6 hrs)**

Molecular structure, internal coordinates, Cartesian coordinates, geometry optimization, frequency analysis, partial charge, MO, Conformational analysis of ethane and butane calculation of some simple chemical problems using computational chemistry programme packages

Recommended Text Books:

1. J. P. Lowe, Quantum Chemistry, 3rd ed., Academic Press, New York, 2008.
2. F. Jensen, Introduction to Computational Chemistry, 2nd ed., Wiley, New York, 2009.
3. R. Leach, Molecular Modeling, Principles and Applications, 2nd ed., Pearson Education, London, 2001.
4. A. K. Chandra, Introduction to Quantum Chemistry, 4th ed., Tata McGraw-Hill, 1994.
5. L. Pauling, E. B. Wilson, Introduction to Quantum Mechanics, McGraw-Hill, 1935.
6. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Book ed., Mc.Graw-Hill, New York, 1982.
7. T. A. Albright, J. K. Burdett, M.-H. Whangbo, Orbital Interactions in Chemistry, 2nd ed., John Wiley and Sons, Inc., Hoboken, New Jersey, 2013.

ORE/LAB

CHE 10806

ADVANCED PHYSICAL CHEMISTRY LAB-II

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Operate various sophisticated instruments.	Apply
C.O.2: Perform experiments based on various laws of physical chemistry.	Apply
C.O.3: I the results obtained from various experiments.	Analyse
C.O.4: Calculate the unknown concentration of the given solution based on the results obtained from the experiment.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x				x	x	x	x	
C.O.2	x	x				x		x	x	
C.O.3	x	x				x		x	x	
C.O.4	x	x		x				x	x	

UNIT – 1 **(96 hrs)**

1. Molecular weight determination by cryoscopic methods, Formula ofcomplexes.
2. Phase diagrams: Two component liquid–liquid and solid-liquid systems.Three component liquid-liquid systems.
3. Determination of transition temperature, molecular weight determination.
4. Refractometry: Variation of refractive index with composition, formula ofcomplexes.
5. Chemical Kinetics: Acid and base catalysed hydrolysis of esters,
6. Dependence of temperature and ionic strength on the rate of reactions, Hydrolysis of p-nitrophenyl acetate using spectrophotometry.
7. Ostwald Viscometer: Viscosity of liquid and liquid mixtures.
8. Conductometry: Cell constant, conductivity of a weak-acid, solubility of asparingly soluble salt, conductometric titrations. Determination of critical micelle concentration of colloids.
9. Poteniometry: Measurement of electrode potentials, activity coefficients and potentiometric titrations, pH metric titrations.
10. Adsorption: Checking the validity of Freundlich and Langmuir adsorptionand determination of unknown concentration.
11. Spectrophotometry: Checking the validity of beer Lambert's law anddetermination of unknown concentration.
12. Demonstration of instrumentation of AAS, Flame photometry, Fluorescence spectrometer, GPC, Electrochemical work station etc.

Recommended Text Books:

1. A. Findlay, Practical Physical Chemistry, 9th ed., Longman, 1973.
2. D. P. Shoemaker, C.W. Garland, J.W, Nibler, Experiments in Physical Chemistry,5th ed., McGraw Hill, 1989.
3. J. B. Yadav, Advanced Practical Physical Chemistry, 36th ed., KrishnaPrakashanMedia (P) Ltd, 2016.
4. J. N. Gurtu, A.N. Gurtu, Advanced Physical Chemistry Experiments, 6th ed.,Pragati, 2014.

CORE/LAB

CHE 10807

OPEN ENDED LAB-IV

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1 : Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validatingthe hypothesis.

The students shall submit a project progress report

ELECTIVE

CHE 10808

BIOANALYTICAL CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Demonstrate key features and characteristics of major biomolecules.	Understand
C.O.2: Describe and explain the principles and applications of MRI and NMR for bioanalysis.	Understand
C.O.3: Outline the principles and theory of major types of electrophoresis and electrophoretic separation.	Apply
C.O.4: Explain the theory and applications of biochemical analysis like RIA, ELISA.	Analyze
C.O.5: Appreciate the variety of popular methods to separate and isolate biomolecules.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x						x		
C.O.2	x	x				x		x		
C.O.3	x	x				x		x		
C.O.4	x	x				x		x		
C.O.5	x	x				x		x		

UNIT – 1 **(10 hrs)**

Biomolecules- amino acid, protein, nucleic acid –structures, physical and chemical properties, features and characteristics of major biomolecules, structure- function relationship, significance. Different methods for the estimation of protein. Transition metals in health and disease - Importance of transition metals in physiological processes, Therapeutic implications of transition metals.

UNIT – 2 **(8 hrs)**

Transmission electron Microscopy (TEM), Scanning electron Microscopy (SEM) – Instrumentation and its biological applications. Nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI) technologies: key tools for the life and health sciences. Principles of NMR and the importance of this biomolecular analytical technique. Established and emerging applications of NMR. Principles and uses of MRI. MRI as a principal diagnostic and research tool.

UNIT – 3 **(4 hrs)**

Electrophoretic techniques – Principles of electrophoretic separation. Types of electrophoresis including paper, gel. Electroporation, Pulse field gel electrophoresis- applications in life and health science.

UNIT – 4 **(4 hrs)**

Radio immune assay (RIA) - principle and applications. Enzyme linked immune sorbent assay (ELISA) principle and applications. Biosensors-applications.

UNIT – 5 **(6 hrs)**

Principle of centrifugation, concept of RCF, features and component of major types of centrifuge, preparative, differential and density gradient centrifugation, analytical ultra-centrifugation, centrifugation. Flow cytometry: principles and applications of this core method of separation.

Recommended Text Books:

1. V. A. Gault, N. H. Mcclenaghan, Understanding bio analytical chemistry –principle and applications, John Wiley and Sons, Ltd Publications, 2009.
2. A. Manz, N. Pamme, D. Iossifidis, Bio-analytical Chemistry, 2004
3. S. R. Mikkelsen, E. Corton, Bio Analytical Chemistry, John Wiley and Sons,Ltd Publications, 2004.
4. K. Wilson, J. Walker, Practical Biochemistry-Principles and techniques, 5th ed., Cambridge University press, 2000.

ELECTIVE

CHE 10809

ADVANCED PHOTOCHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe various photochemical and photophysical processes and apply established experimental methods for the investigation of these processes.	Apply
C.O.2: Explain theories of photoinduced electron transfer and reactivity of excited states and their significance in different fields including biomedical applications and photosynthesis.	Evaluate
C.O.3: Apply the knowledge of photochemistry of semiconductors and advanced materials for various applications involving photochemical energy conversions.	Apply
C.O.4: Explain theory and application of photocatalysis and explain the environmental impact of atmospheric photochemistry.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x						x		
C.O.2	x	x						x		
C.O.3	x	x			x			x		
C.O.4	x	x	x		x			x		

UNIT – 1 **(8 hrs)**

Energy Transfer-Theories of Energy Transfer – Photosensitization of Organic and Inorganic Molecules – Singlet Oxygen – Methods of singlet oxygen generation nd Detection – Chemistry of Singlet Oxygen – Photodynamic Therapy of Cancer.

UNIT – 2 **(8 hrs)**

Photoinduced Electron Transfer – Theory of Electron transfer – CircumventingBack Electron transfer – Photoinduced Electron transfer reactions of Organic and Inorganic Molecules – Photosynthesis.

UNIT – 3 **(4 hrs)**

Photochemistry and Photophysics of Semiconductors – Semiconductor Photocatalysis and applications. Atmospheric photochemistry

UNIT – 4 **(6 hrs)**

Photochemistry and Advanced Materials - Artificial Solar Energy Harvesting – Photochemical Splitting of Water – Dye sensitized solar cells - Grätzel Cell - Bulk heterojunction devices for solar energy harvesting - Organic light emitting devices. Photoresists – Photolithography – Photochromism – Photonic Materials and Lasers.

UNIT – 5 **(6 hrs)**

Photochemistry in Practice – Radiometry and Actinometry – Principles ofRadiometry and radiometers – Actinometry – Quantum Yields – Light Sources – Optical Materials and Filters – Photochemical Reactors.

Recommended Text Books:

1. N. J. Turro, V. Ramamurthy, J. C. Scaiano, Modern Molecular Photochemistry of Organic Molecules, University Science Books, 2010.
2. C.E. Wayne, Photochemistry (Oxford Chemistry Primers), Oxford UniversityPress; 1st ed., 1996.
3. J. R. Lakowicz, Principles of Fluorescence Spectroscopy, Plenum Press, 3rd ed.,2010.
4. A. M. Braun, M.-T. Maurette, Esther Oliveros, Photochemical Technology, JohnWiley & Sons, 1991.
5. M. A. Fox, M. Chanon, Photoinduced Electron Transfer Part A, B. C and D,Elsevier Science Publishing Company, 1988.
6. J. Mattay Ed., Photoinduced Electron Transfer 1-5 (Topics in Current Chemistry), Springer, 1st ed., 1990-1993.

7. G. J. Kavarnos, Fundamentals of Photoinduced Electron Transfer, 1st ed., Wiley- V CH, 1993.
8. V. Ramamurthy, K. Schanze, Molecular and Supramolecular Photochemistry, Volume 10 Semiconductor Photochemistry and Photophysics, Marcel Dekker,New York, 2003.
9. V.Ramamurthy, Photochemistry in Organized and Confined Media, VCH Publishers, New York, 1991.

ELECTIVE

CHE 10810

THEORY OF ORBITAL INTERACTIONS IN CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Examine the physical properties associated with molecules and the pathways taken by chemical reactions.	Analyse
C.O.2: Correlate qualitatively the shape and energy of orbitals and the chemical reaction exhibited by any molecule.	Apply
C.O.3: Explore the effects of symmetry, overlap, and electronegativity in the molecular orbital in case of chemical reaction.	Evaluate
C.O. 4: Explore the structures and reactivity relationships associated with any molecule.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		

UNIT – 1 **(6 hrs)**

Atomic and Molecular Orbitals, Concepts of Bonding and Orbital Interaction, Orbital Interaction Energy, Molecular Orbital Coefficients, Electron Density Distribution, Perturbational Molecular Orbital Theory, Linear H_3, HF, and the Three-Orbital Problem.

UNIT – 2 **(10 hrs)**

Molecular Orbital Construction from Fragment Orbitals, Triangular H_3, Rectangular and Square Planar H_4, Tetrahedral and Linear H_4, Pentagonal H_5 and Hexagonal H_6, Molecular Orbitals of Diatomic Molecules and Electronegativity Perturbation, Geometrical Perturbation of Molecular orbitals, Molecular Orbitals of AH_2, Walsh Diagrams, Jahn–Teller Distortions.

UNIT – 3 **(6 hrs)**

Molecular Orbitals of Small Building Blocks, AH System, AH_3 Systems, pi- Bonding Effects of Ligands, AH_4 System, Molecules with Two Heavy Atoms, A_2H_6 Systems, Orbital Interactions through Space and through Bonds.

UNIT – 4 **(4 hrs)**

Polyenes and Conjugated Systems, Acyclic Polyenes, Huckel Theory, Cyclic Systems, Conjugation in Three Dimensions, Solids, Energy Bands, Hypervalent Molecules.

UNIT – 5 **(6 hrs)**

Transition Metal Complexes. Octahedral ML_6, pi-Effects in an Octahedron, Distortions from an Octahedral Geometry, Square Planar, Tetrahedral ML_4 Complexes, Five Coordination, Square Pyramidal ML_5 Fragment, ML_3 Fragment, ML_2 and ML_4 Fragments, M_2L_8 Dimers, CpM and Cp_2M, Isolobal Analogy.

Recommended Text Books:

1. T. A. Albright, J. K. Burdett, M.-H. Whangbo, Orbital Interactions inChemistry, 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., Wiley-Blackwell, 2000.
4. W. L. Jorgensen, L. Salem, The Organic Chemist's Book of Orbitals, Academic Press, 1973.

CORE

CHE 10901

ANALYTICAL CHEMISTRY-II

(ADVANCED ANALYTICAL TECHNIQUES AND INSTRUMENTAL METHODS)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Explain the theory, instrumentation and applications of various electroanalytical techniques, chromatographic, thermal and surface analysis	Apply
C.O.2: Predict appropriate chromatographic methodology for separation of a given mixture	Analyse
C.O.3: Perform separation of components in a mixture using GC-MS and HPLC	Evaluate
C.O.4 : Perform individual and simultaneous voltammetric analysis of samples	Evaluate
C.O. 5 : Analyse the surface of various samples using SEM, AFM, TEM	Analyse

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x									
C.O.2	x	x								
C.O.3	x	x	x	x		x	x		x	
C.O.4	x	x	x	x		x	x		x	
C.O. 5	x	x	x	x						

UNIT – 1 **(18 hrs)**

Potentiometry: different types of indicator electrodes, limitations of glass electrode, applications in pH measurements, othertypes of ion selectiveelectrodes, 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.

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

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 simultaneousanalysis-Case study

UNIT – 2 **(12 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 theparameters-Temperature, Length of the column, Sample size, Flow rate CHN analysis by GC, Case study GC 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 chromatograph .and GC-MS applications.

UNIT – 3 **(12 hrs)**

HPLC – 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.

UNIT – 4 **(12 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 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.

UNIT – 5 **(10 hrs)**

Chemical Analysis of surfaces: Surface preparations-ion scattering spectrometry secondary ion scattering microscopy (SIMS)-Auger election spectroscopy-ESCA instrumentation and application. Principle, instrumentation and applications of SEM, TEM and AFM, Case study

Recommended Text 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 AnalyticalChemistry, 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 ofQuantitative 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.
16. Allen J. Bard, Larry R. Faulkner, Electrochemical Methods-Fundamentals and Applications, John Wiley & Sons, NewYork, 1980.

CORE

CHE 10902

Inorganic Chemistry – V

(ORGANOMETALLIC AND BIOINORGANIC CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Distinguish the different types of ligands with respect to the type of interaction with the metal.	Analyse
C.O. 2: Evaluate the structure, bonding and reactions of organometallic compounds and metal clusters.	Evaluate
C.O.3: Predict the stability of organometallic compounds and metal clusters.	Apply
C.O.4: Explain the application of reactions of organometallic complexes in homogeneous catalytic processes.	Apply
C.O.5: Identify the role of metals in biological systems.	Apply

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x						x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		
C.O.5	x	x						x		

UNIT – 1 **(8 hrs)**

Compounds with transition metal to carbon bonds: eighteen electron rule; classification of ligands, nomenclature, σ donor ligands – metal alkyl, aryl complexes; σ donor/π acceptor ligands, – metal alkenyls, alkynyls, carbenes, carbynes, carbonyls, isocyanide, fluxionality of ligands – structure, bonding, spectra, preparation and reactions.

UNIT – 2 **(8 hrs)**

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.

UNIT – 3 **(8 hrs)**

Metal–Metal bonds and Transition metal clusters; preparation, properties andspectroscopy. Parallels with nonmetal chemistry- isolobal analogy. Application of Wade-Mingos-Lauher rules in predicting thestructure of organometallic clusters

UNIT – 4 **(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.

UNIT – 5 **(12 hrs)**

Metal ions in biological systems: Heme proteins – hemoglobin, myoglobin Non-Heme Iron Proteins: Iron storage and transfer – ferritin, transferrin; electron transfer (Iron-sulfur protein) – rubredoxin, ferredoxin; O2 transport – hemerythrin Copper proteins and Enzymes – Hemocyanin, superoxide dismutase, ceruloplasmin, cytochrome coxidase; Zinc and Cobalt enzymes – carbonic anhydrase, carboxypeptidase, interchangeability of zinc and cobaltenzymes; Vitamin B12 and B12 Photosynthesis and N2 fixation Metals in medicines and therapy.

Recommended Text Books:

1. Ch. Elschenbroich, A. Salzer, Organometallics – A Concise Introduction, VCHPublishers, 1989.
2. B. D. Gupta, A. J. Elias, “Basic Organometallic Chemistry”, University Press,2010.
3. P. Powell, Principles of Organometallic Chemistry, 2nd ed., ELBS, 1991.
4. J. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles ofstructure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
5. E.-I. Ochiai. Bioinorganic Chemistry – An Introduction, Allyn and Bacon Inc.,1977.
6. N. Kaim, B. Schwederski. Bioinorganic Chemistry: Inorganic Elements in theChemistry of Life, John Wiley, 1994.
7. Bertini, H. B. Gray, S. J. Lippard, J. S. Valentine, Bioinorganic Chemistry, VivaBooks, 1998.
8. R. W. Hay, Bio Inorganic Chemistry, Ellis Horwood, 1987.
9. J. A. Cowan, Inorganic Biochemistry – An Introduction, 2nd ed., VCH, 1997.
10. N. S. Hosmane (Ed) Boron Science: New Technologies and Applications, CRCPress, 2011.
11. S. J. Lippard, J. M. Berg. Principles of Bioorganic Chemistry, Panima Publ.Corpn. 2005.
12. M. N. Hughes, The Inorganic Chemistry of Biological Processes, Wiley, 1981.

CORE

CHE 10903

ORGANIC CHEMISTRY-VI

(CHEMISTRY OF NATURAL PRODUCTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Device synthesis scheme for heterocyclic aromatic and nonaromatic organic compounds.	Analyse
C.O.2: Elucidate structure and device synthesis for important natural products.	Apply
C.O.3: Describe molecular structure of carbohydrates, proteins, DNA, RNA and synthesis of vitamin C and shikimic acid.	Understand

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x	x					x		
C.O.2	x	x	x					x		
C.O.3	x	x	x					x		

UNIT – 1 **(6 hrs)**

Nomenclature and general characteristics of heterocyclic compounds. Structure, properties, synthesis and reactivity of three and four-membered ring heterocyclescontaining one heteroatom.

UNIT – 2 **(10 hrs)**

Heteroaromatic compounds (five and six-membered rings) containing one or two heteroatoms.
Fused ring compounds: Synthesis and properties of indole,quinoline, isoquinoline, coumarin, flavone, purine and pyrimidine bases present in nucleosides.

UNIT – 3 **(12 hrs)**

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

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

UNIT – 4 **(10 hrs)**

Carbohydrates: Structure of ribose, glucose, fructose, maltose, sucrose, lactose, starch cellulose and cyclodextrins. Preparation of alditols, glycosides (O, C, and N), deoxysugars. Synthesis of Vitamin C from glucose. Nucleic acids: Structure and synthesis, genetic code, recombinant DNA, biosynthesis of shikimic acid.

UNIT – 5 **(10 hrs)**

Aminoacids, peptides and enzymes: Synthesis of aminoacids – Strecker and azalactone synthesis, enantioselective synthesis of aminoacids, reactions of aminoacids. Structure of proteins, introduction to enzymes and coenzymes with special reference to the function of chymotrypsin, NAD, thiamine, pyridoxal. In vitro and in vivo synthesis of peptides, solid phase synthesis.

Recommended Text Books:

1. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
2. I. L. Finar, Organic Chemistry Volumes 1 & 2, 6th ed., Pearson Education Asia, 2004.
3. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
4. N. R. Krishnaswamy, Chemistry of Natural Products; A Unified Approach, Universities Press, 1999.
5. R. J. Simmonds, Chemistry of Biomolecules: An Introduction, RSC, 1992.
6. R. O. C. Norman, Principles of Organic Synthesis, 2nd ed., Chapman and Hall, 1978.
7. J. A. Joule, K. Mills, Heterocyclic Chemistry, 5th ed., Wiley, 1998.
8. J. J. Li, E. J. Corey, Total Synthesis of Natural Products: At the Frontiers ofOrganic Chemistry, Springer, 2012.
9. T. Eicher, S. Hauptmann, The Chemistry of Heterocycles, 2nd ed., Wiley, 2003.
10. K. C. Nicolaou, S. A. Snyder, Classics in Total Synthesis II: More Targets, Strategies, Methods, Wiley, 2003.

CORE

CHE 10904

PHYSICAL CHEMISTRY-IV

(CHEMICAL KINETICS, REACTION DYNAMICS, CATALYSIS AND SURFACE CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Interpret the basic reaction dynamics and obtain the rate constantsfor reactions in gaseous state and solutions.	Analyse
C.O. 2: Calculate thermodynamic parameters from kinetic data.	Apply
C.O. 3: Interpret the kinetics of unimolecular, termolecular and fastreactions.	Apply
C.O. 4: Identify isotope effects in reactions	Analyse
C.O. 5: Apply the principles of acid-base and enzyme catalysis to solveany given kinetic data.	Analyse

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					
C.O.5	x	x			x					

UNIT – 1 **(8 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-Semenov Hinshelwood mechanism (H_2-O_2 reaction), Fast Reactions- Relaxation methods- Perturbations, Flash photolysis and Pulseradiolysis.

UNIT – 2 **(10 hrs)**

Molecular reaction dynamics: Reactive encounters, Theories of reaction rates- Collision Theory. Collision and reaction cross section. Activated Complex Theory- PES, 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

UNIT – 3 **(10 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.

UNIT – 4 **(10 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.

Physical and chemical adsorption. Adsorption isotherms- Langmuir (kinetic and statistical derivation), Freundlich and BET (derivation) isotherms, Determination of surface area using Langmuir and BET isotherms, Isosteric heat of adsorption.

Thermodynamics of adsorption- Gibbs adsorption isotherm.

UNIT – 5 **(10 hrs)**

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

Autocatalysis- Oscillatory reactions- Lotka- Volterra, Oregonator, Brussellator.

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.
8. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York.
9. K. J. Laidler, Chemical-Kinetics, McGraw Hill, New York.
10. M. R. Wright, An Introduction to Chemical Kinetics, Wiley, 2004.
11. A. Somorjai, Chemistry of Surfaces, 3rd Edn. Wiley, New York.
12. Clark, “Theory of adsorption and catalysis”, Academic Press, 1970.
13. J.M. Thomas & W.J. Thomas, “Introduction to principles of heterogeneous catalysis”, Academic Press, New York, 1967.
14. R.H.P. Gasser, “An introduction to chemisorption and catalysis by metals”, Oxford, 1985.
15. D.K Chakraborthy, “Adsorption and catalysis by solids”, Wiley Eastern Ltd. 1990.

CORE

CHE 10905

PHYSICAL CHEMISTRY-V

ADVANCED ELECTROCHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: describe the theories effecting ionic conductance and apply the concepts to calculate conductance behaviour of a given system.	Apply
C.O.2: describe the electronic conductance behaviour in charged interfaces and analyse the catalytic behaviour of a system.	Analyse
C.O.3: learn the working principle and advancement in futuristic electrochemical devices.	Understand

	Programme Outcomes							
Course Outcomes	**P.O.1**	**P.O.2**	**P.O.3**	**P.O.4**	**P.O.5**	**P.O.6**	**P.O.7**	**P.O.8**
C.O.1	x	x						x
C.O.2	x	x						x
C.O.3	x	x				x		x

UNIT – 1 **(6 hrs)**

Review of basic concepts, Ionic Conductance, Ion Solvent Interactions, Ion-Water Interactions, Coordination Number, Solvation numbers, Hydration of simple cation, anion, and transition metal ion. Ion-Ion Interaction, Debye-Huckel Theory, Ionic Atmosphere, time of Relaxation, Mechanism of Electrolytic Conductance, Linearized P-B equation, Activity and Activity Coefficient of Electrolytes, Validity of Deby-Huckel theory., Debye-Hückel limiting law, Debye-Hückel-Bronsted Equation.

UNIT – 2 **(8 hrs)**

Ion transport, Fick's law of diffusion, Diffusion Coefficient, Ionic drift in presence of electric field, drift velocity, transport number, Debye-Huckel- Onsager Equation, Relaxation effect, time of relaxation, Determination of degree of dissociation, Debye-Falkenhagen Effect, Wien Effect.

Ionic liquids, Limiting case of zero solvent-pure electrolyte, features of ionic liquid, diffusion in IL, ionic conductance IL, liquid oxide electrolytes.

UNIT – 3 **(8 hrs)**

Electrodics, Charged Interfaces, Electrode Potential, Factors Influencing electrode potential, Band Bending, electrolytic polarization, dissolution and decomposition potential, concentration polarization. Concentration cells.

Structure of electrified interfaces, liquid junction potential, the electrode double layer, electrode-electrolyte interface, different models of double layer, theory of multilayer capacity, electrocapillary, Lippmann equation, membrane potential.

UNIT – 4 **(6 hrs)**

Electrode kinetics, Ion adsorption, Electron Transfer Under an Interfacial Electric Field, Overvoltage, theories of overvoltage, Tafel equation, Butler-Volmer equation. Electrocatalyst-Homogeneous, heterogeneous, Randles-Sevcik Equations, Pourbiax diagrams, PCET.

UNIT – 5 **(4 hrs)**

Semiconductor electrode interface. Band bending, photoelectrochemistry, fuel cells, battery-metal –ion, metal-air battery, Corrosion, Bioelectrochemistry – nervous system,enzyme as electrodes.

Recommended Text Books:

1. J. Bockris, A. K. N. Reddy, Modern Electrochemistry-1 Ionics, 2nd ed., Springer Science & Business Media, 2018.
2. J. Bockris, A. K. N. Reddy, M. E. Gamboa-Aldeco, Modern Electrochemistry- 2A: Fundamentals of Electrodics, 2nd ed., Springer Science & Business Media, 2018.
3. J. Bockris, A. K. N. Reddy, Modern Electrochemistry 2B: Electrodics in Chemistry, Engineering, Biology and Environmental Science, 2nd ed., Springer Science & Business Media, 2018.
4. R. Crow, Principles and Applications of Electrochemistry, 4th ed., 1994.
5. S. Glasstone, An Introduction to Electrochemistry, Paperback ed., 2007.

CORE/LAB

CHE 10906

OPEN ENDED LAB-V

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validatingthe hypothesis. The students shall submit a project report and appear for viva-voce.

ELECTIVE

CHE 10907

OLEOCHEMICALS, NUTRACEUTICALS AND SURFACTANT TECHNOLOGY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Able to classify and demonstrate the use of oils.	Apply
C.O.2: Analyse and characterize oleocemicals, nutraceuticals and surfactants.	Analyse
C.O.3: Evaluate the techniques of preparation and purification of oils.	Evaluate
C.O.4: Prepare formulation of soaps, detergents and cosmetics.	Create

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x						x		
C.O.2	x	x		x				x		
C.O.3	x	x					x	x		
C.O.4	x	x	x		x			x		

UNIT – 1 **(8 hrs)**

General Introduction, Sources of edible oils and fats, Processing and refining, Stability and Antioxidants, Analysis testing and QC. Introduction to essential oilsand comparison with other oils. Raw materials, processing, purification and isolation of essential oil, Conventional and advance methods of production of essential oils, Synthetic Aroma chemicals and aromatherapy, Physicochemical and sensory Analysis and quality control in industry , Detail study of selected essential oils related to production, isolation, applications etc. (3 examples), Applications in soaps, detergents, cosmetics industry, flavors etc. Oleochemical Industry and Market Information.

UNIT – 2 **(8 hrs)**

Introduction to nutraceuticals: definitions, synonymous terms, claims for a compound as nutraceutical, regulatory issues. Study of Properties, structure and functions of various Nutraceuticals (3 examples) formulation of functional food, stability, analysis. Food as remedies, Anti-nutritional Factors present in Foods, Nutraceutical Industry and Market Information.

UNIT – 3 **(4 hrs)**

Soaps and Detergent – Introduction, Chemistry, Classification, Manufacture and Environmental aspects, Analysis of Soaps surfactants and detergents: determination of surface tension, interfacial tension, and CMC, Testing of TFM of soap, % active matter of detergents.

UNIT – 4 **(6 hrs)**

Recent developments- Spray Dried Powdered Detergents, Concept of HLB and other related terms, detersive system, micro emulsion, multiple emulsion system, nanoemulsion system. Disinfectants, Surfactant Industry and Market Information.

UNIT – 5 **(6 hrs)**

Hydraulic expelling, Solvent extraction and separation of oils and fats, Aqueous extraction, Liquid liquid extraction for deacidification, Miscella refining anddouble solvent refining, High pressure fat splitting, fatty acid distillation, Saponification of Oils, Soap formulation and Plodder Processing, Synthesis various anionic, cationic, nonionic and amphoterric surfactants, Formulation and Processing of Detergent Powder by combined absorption and neutralisation mode**,** Purification of wax, Formulation and Processing of different Skin and Hair Care Products. Production Management, Marketing.

Recommended Text Books:

1. B.K. Sharma, Industrial Chemistry, GOEL Publishing House, 2000.
2. Mohammad Farhat Ali, Bassam Ali, James Speight, Handbook of Industrial Chemistry Organic Chemicals, McGraw-Hill 2005.
3. O. P. Narula, Treatise on fats, fatty acids and oleochemicals by, Industrial Consultants (India), Vo. I & II, 1994.
4. V. V. S. Mani and A. D. Shitole, Fats, Oleochemicals and surfactants challengesin 21st Century by Oxford and IBH Publishing Co. Pvt. Ltd., 1997.
5. Robert E. C. Wildman, Handbook of Nutraceuticals and Functional Foods, CRC Press 2016.

ELECTIVE

CHE 10908

MATERIALS CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Evaluate a material in terms of its properties and device plausiblesynthetic strategies.	Analyse
C.O. 2: Suggest the applicability of a given material for a specific application.	Analyse

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x						x	x	
C.O.2	x	x		X				x	x	

UNIT – 1 **(8 hrs)**

Chemistry of Materials. Historical perspectives – strategies for the design of new materials- a critical thinking approach. 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. Amorphous materials – glasses and ceramic solids. Structural organization of amorphous solids. Traditional ceramics. Synthetic high performance ceramics. Crystal structure of ceramics.

UNIT – 2 **(8 hrs)**

Metals and alloys. Structural and bonding theories of metals. Alloys -ferrous alloys – phase behavior of ferrous alloys. Behaviour of binary alloys. Intermediate compounds and intermediate phases. Nonferrous metals and alloys. Shape memory alloys. PZT materials. Optical, electrical and magnetic properties of metallic materials.

UNIT – 3 **(4 hrs)**

Semiconductor materials- properties and types of semiconductors. Structure and Bonding of semiconductor materials. Silicon based semiconductors. II-VI (wide band gap) and IIIV (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.

UNIT – 4 **(6 hrs)**

Polymer Materials- classification and nomenclature of polymers. Methods of Polymerization. Dendritic and cascade polymers. Polymers via Click Chemistry. Properties of polymers. Plastics and elastomers. Viscoelastic behavior. Rubber like elasticity. Conducting polymers. Crystalline and amorphous polymers. Glass transition temperature and crystalline melting. Polymer composites- polymer matrix composites.

UNIT – 5 **(6 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 and properties. 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. Energy and environmental applications.

Recommended Text Books:

1. Fahlman, B. D. Materials Chemistry, 2nd Ed., Springer, Heidelberg,2011.
2. Zallen, R. Physics of Amorphous Solids, Wiley, New York,1983.
3. Borg, R. J. and Dienes, G. J. The Physical Chemistry of Solids, Academic Press, Boston,1993.
4. Kingery, D.; Bowen, H. K.; Uhlmann, D. R. Introduction to Ceramics, 2nd Ed., Wiley, New York,1992.
5. Cowie, J. M. J. Polymers. Physics and Chemistry of Modern Materials, 3rd Ed., CRC Press, Boca Raton, 2007.
6. Kasap, S. O. Principles of Electronic Materials and Devises, Mc GrawHill,2006.

MOOC ELECTIVE

CHE 10909

CHEMICAL CRYSTALLOGRAPHY

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Apply the concepts and applications of widely used experimental technique of X-ray crystallography	Analyse
C.O.2: Describe the wider significance of symmetry operation in understanding the crystal structure	Apply
C.O.3: Understand the experimental techniques for crystal preparation and selection	Understand
C.O.4: Understand the theoretical calculations involved in extracting structural information from diffraction patterns	Understand
C.O.5: Perform structure determination and refinement of crystal structures using x-ray diffraction data and software packages.	Evaluate

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x				x		x		
C.O.2	x	x				x		x		
C.O.3	x	x					x	x		
C.O.4	x	x						x		
C.O.5	x	x				x	x	x		

UNIT – 1 **(12 hrs)**

Introduction, 1D symmetry, Concept of 2D symmetry and lattices, notations of symmetry elements, space groups in 2D, 3D lattices, 32 point groups and their notations, crystal systems and Bravais lattices. Stereographic projections, Laue symmetry; glide planes, screw axes and their notations, space groups, equivalent points, space group symmetry diagrams etc. Miller Indices, crystallographic planes and directions, close pack structures, linear density, planar density, Miller-Bravais indices for hexagonal systems, various ceramic structures (NaCl, ZnS, CaF2, CsCl etc.), octahedral and tetrahedral sites.

UNIT – 2 **(12 hrs)**

What are X-rays, generation and classification of X-ray, X-ray sources, diffraction of X- rays, Bragg's law. The reciprocal lattice, reciprocal relationship, Bragg's law in reciprocal space, Ewald's sphere and sphere of reflection , Methods of crystal growth, identification of phases and morphologies, in-situ cryo crystallization, crystal growth under external stimuli etc.

UNIT – 3 **(12 hrs)**

Data collection strategies, Laue Method, Oscillation, rotation and precession methods. L- P corrections, structure factor, scaling, interpretation of intensity data, temperature factor, symmetry from intensity statistics, Structure factor and Fourier synthesis, Friedel's law; exponential, vector and general forms of structure factor, determination of systematic absences for various symmetry or lattice centering, FFT, Anomalous scattering and absolute configuration.

UNIT – 4 **(12 hrs)**

Phase problem, Direct Methods, structure invariants and semi invariants, probability methods, Phase determination in practice, Patterson Methods, Patterson Symmetry, completion of structure solution, ΔF synthesis, Refinement by Fourier synthesis, refinement by ΔF synthesis, Refinement by least squares method, weighting functions, Goodness-of-Fit (GOF) parameter, treatment of non-hydrogen atoms, and treatment of hydrogen atoms, treatment of disordered structures.

UNIT – 5 **(16 hrs)**

Crystal selection, indexing of crystals, data collection, data reduction, space group determination, structure solution and refinement using SHELXS97 and SHELXL97, introduction to crystallographic packages (APEX II suite, OLEX2, WinGx, PLATON) and IUCr validation of the data, Methodology, geometrical basis of powder X-ray diffraction, applications of PXRD: determination of accurate lattice parameters, identification of new/unknown phases, applications in pharmaceutical industry. Applications of powder X-ray diffraction: Structure determination from PXRD and Reitveld method for structure refinement, indexing of PXRD, handling of PXRDusing DASH.

Recommended Text Books:

1. X-ray structure determination: A Practical Guide (2nd Ed.) by George H.Stout and Lyle H Jensen, Wiley-Interscience, 1989.
2. Fundamentals of Crystallography (2nd Ed.) by C. Giacovazzo, OxfordUniversity Press, 2002
3. X-ray analysis and The Structure of Organic Molecules (2nd Ed.) Wiley-VCH, 1996
4. Chemical Applications of Group Theory (3rd Ed.) by F. A. Cotton, Wiley-India Edition, 2009.
5. The Basics of Crystallography and Diffraction by Christopher Hammond. Oxford University Press, 2015
6. Crystal Structure analysis A Primer by Jenny Pickworth Glusker and Kenneth N. Trueblood, Oxford University Press, 2010
7. Crystal Structure Analysis Principles and Practices by A. J. Blake, W. Clegg, J. M. Cole, J. S. O. Evans, P. Main, S. Persons and D. J. Watkin. OxfordUniversity Press, 2009.
8. Crystal Structure Refinement A Crystallographer's Guide of SHELXL by P. Muller, R. Herbst-Irmer, A. L. Spek, T. R. Schneider and M. R. Sawaya, Oxford University Press, 2006
9. Crystal Structure Determination by Werner Massa. Springer, 2013.

Credit 16 **CHE 11001** **CORE/LAB**

PROJECT DISSERTATION

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Identify and hypothesise an advanced level research problem.	Create
C.O.2: Design experiments and validate the hypothesis of an advanced level research problem.	Create

	Programme Outcomes									
Course Outcomes	**P.O. 1**	**P.O. 2**	**P.O. 3**	**P.O. 4**	**P.O. 5**	**P.O. 6**	**P.O. 7**	**P.O. 8**	**P.O. 9**	**P.O. 10**
C.O.1	x	x	x	X	x	x		x	x	
C.O.2	x	x	x	X	x	x	x	x	x	

UNIT – 1

The students shall carry out research project in reputed research laboratory for theentire 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 seminarand appear for a comprehensive viva-voce.

Guide lines for setting up Question Papers in TheoryCourses

- The entire syllabus must be covered in the question paper.
- Each question must be mapped to a specific C.O.
- All the C.O.s must be reflected in the question paper.
- The question paper may consist of questions at different cognitive levels such that, 20% of “remember” level, 40% of “understand” level and 40% of “apply and higher” level.

END

DEPARTMENT OF MATHEMATICS

Scheme of Examination and Syllabus for the Five Year
Integrated M.Sc. Mathematics Program
Approved by the Board of Studies in Physical and Mathematical Sciences
on 17/07/2021

(From 2021 admission onwards)

Cochin University of Science and Technology Cochin -
682 022

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MAM10501:

MAM10502:

MAM10503: Analysis II

MAM10504: Ordinary and Partial Differential Equations

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Qc Department of Mathematics CUSATTABLE OF CONTENTS

Five Year Integrated MSc

Maths Syllabus 2021

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MAM10802: Functional Analysis

MAM10803: Complex Analysis

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MAM10805: Functions of Several Variables and Geometry

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MAM10901: Operator Theory MAM10902:
Topology II
MAM10903: Ordinary Differential Equations and Integral Equations MAM10904: Probability Theory

Semester X

MAM11001: Partial Differential Equations and Variational Problems

LIST OF ELECTIVE COURSES

MAM 10905 : Topics in Applied Mathematics (Inter-departmental elective)
MAM 11002 : Wavelets
MAM 11003 : Optimization & Mathematical Methods For Deep Learning
MAM 11004 : Commutative Algebra
MAM 11005 : Graph Theory
MAM 11006 : Advanced Linear Algebra MAM
11007 : Discrete Framelets
MAM 11008 : Harmonic Analysis
MAM 11009 : Integral Transforms
MAM 11010 : Functions Of Several Variables
MAM 11011 : Advanced Spectral Theory
MAM 11012 : Banach Algebras And Spectral Theory
MAM 11013 : Number Theory
MAM 11014 : Representation Theory Of Finite Groups
MAM 11015 : Algebraic Topology
MAM 11016 : Differential Geometry

Scheme

SEMESTER V

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	**End semester**	**Total**	**Credit**
MAM 10501	Analysis I	C	50	50	100	4
MAM 10502	Linear Algebra & Geometry in R^n	C	50	50	100	4
MAM 10503 Algebra:	Algebra: Groups and Rings	C	50	50	100	4
MAM 10504	Introduction to Complex Analysis	C	50	50	100	4
STA 10501 tatistics	Statistics and Probability II	C	50	50	100	4
	Total		**250**	**250**	**500**	**20**

SEMESTER VI

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	**End semester**	**Total**	**Credit**
MAM10601	Analysis II	C	50	50	100	4
MAM10602 ODE and	ODE and PDE	C	50	50	100	4
MAM10603	Comp1exAnalysis & NumberTheory	C	50	50	100	4
MAM**** Elective I	Elective I	E	50	50	100	4

MAM**** Elective II	Elective II	E	50	50	100	4
	Total		**250**	**250**	**500**	**20**

SEMESTER VII

Course Code	Name of the Course	Credits
MAM10701	Linear Algebra	4
MAM10702	Real Analysis	4
MAM10703	Measure and Integration	4
MAM10704	Groups and Rings	4
MAM10705	Computational Mathematical Laboratory	4
	VIVA VOCE	
Total Credits		**20**

SEMESTER VIII

Course Code	Name of the Course	Credits
MAM10801	Fields and Modules	4
MAM10802	Functional Analysis	4
MAM10803	Complex Analysis	4
MAM10804	Topology I	4
MAM10805	Functions of Several variables & Geometry	4
	VIVA VOCE	
Total Credits		**20**

SEMESTER IX

Course Code	Name of the Course	Credits
MAM10901	Operator Theory	4
MAM10902	Topology II	4
MAM10903	Ordinary Differential Equations & Integral	4

	Equations	
MAM10904	Probability Theory	4
MAM*****	Elective I	3
	VIVA VOCE	
Total Credits		**19**

SEMESTER X

Course Code	Name of the Course	Credits
MAM11001	Partial Differential Equations & Variational Calculus	4
MAM*****	Elective II	4
MAM*****	Elective III	4
MAM*****	Elective IV	4
MAM*****	Elective V	4
	VIVA VOCE	1
	Project (Optional)	8
Total Minimum Credits		**21**

Project is optional to the students. The students opt for project shall start the work immediately after the eighth semester. The project is equivalent to two Electives in the fourth semester.

LIST OF ELECTIVE COURSES

1. MAM 10905 : TOPICS IN APPLIED MATHEMATICS
   (Inter-departmental elective)
2. MAM 11002 : WAVELETS
3. MAM 11003 : OPTIMIZATION & MATHEMATICAL METHODS FOR DEEP LEARN- ING
4. MAM 11004 : COMMUTATIVE ALGEBRA
5. MAM 11005 : GRAPH THEORY
6. MAM 11006 : ADVANCED LINEAR ALGEBRA
7. MAM 11007 : DISCRETE FRAMELETS
8. MAM 11008 : HARMONIC ANALYSIS
9. MAM 11009 : INTEGRAL TRANSFORMS
10. MAM 11010 : FUNCTIONS OF SEVERAL VARIABLES
11. MAM 11011 : ADVANCED SPECTRAL THEORY

12. MAM 11012 : BANACH ALGEBRAS AND SPECTRAL THEORY
13. MAM 11013 : NUMBER THEORY
14. MAM 11014 : REPRESENTATION THEORY OF FINITE GROUPS
15. MAM 11015 : ALGEBRAIC TOPOLOGY
16. MAM 11016 : DIFFERENTIAL GEOMET

Detailed Syllabus of Semester V, VI, VII, VIII, IX, X

Semester V: Analysis I

Course Code: MAM 10501

Course is to be taught in: V Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 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: Creative skills to better understand abstract concepts, skill to construct proofs.

Text book:

1R.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, McGraw Hill Publishi (1964).

Syllabus

Module 1. Sets and Functions, Mathematicle Induction, Finte and Infinite Sets, The Algebraic and Order Properties of R, Absolute Value and Real Line and The completeness Property of 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 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. (Sec- tions 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 : Linear Algebra and Geometry in R*n*

Course Code: MAM 10502

Course is to be taught in: V Semester Integrated

M. Sc. Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course is a continuation of the course on vector spaces with major focus on concepts in geometry in R*n*. Multi-variable differentiation in R*n* is a major foundation course in geometry. In the last two modules basic topics on curves and surfaces are introduced.

Outcome: After completing the course, the student is expected to become familiar with the funda- mental concepts and applications of linear algebra and geometry

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. A basic course in Analysis that includes differentiation in single variable.

Text books:

1. S. Kumaresan, *Linear Algebra: A Geometric Approach*, PHI Learning, 2009.
2. Terrence Tao, *Analysis II*, Hindustan Book Agency, Third Edition, Reprint 2017.
3. Theodore Shifrin: *Differential Geometry: A first course in curves and surfaces*, 2016.

Reference books:

1. Andrew Pressley: *Elementary Differential Geometry*, Springer, 2000.
2. Sheldon Axler, *Linear Algebra Done Right*, 3rd edition. Undergraduate Texts in Mathematics
3. Michael Artin, *Algebra*, Prentice Hall, Inc., Englewood Cliffs, NJ, 1991.
4. Michael Spivak, *Calculus on Manifolds: A mordern approach to classical theorems of advanced calculus*
5. Manfredo Do Carmo, *Differential Geometry of curves and surfaces.*

Syllabus

Module 1. Inner Product Spaces, Orthogonality, Some Geometric Applications, Orthogonal Projec- tion Onto A Line, Orthonormal Basis. (Chapter 5, Sections 5.1, 5.2, 5.3, 5.4, 5.5 of Textbook 1)

Module 2. Orthogonal Complements and Projections, Linear Functionals and Hyperplanes, Orthog- onal Transformations, Reflections and Orthogonal Maps of the Plane.
(Chapter 5, Sections 5.6, 5.7, 5.8, 5.9 of Textbook 1)

Module 3. Linear Transformations, Derivatives in several variable calculus, Partial and Directional Derivatives, The several variable calculus chain rule. (Chapter 6, Sections 6.1, 6.2, 6.3, 6.4 of Text book 2)

Module 4. Curves, Examples, Arclength Parametrization, Local Theory: Frenet Frame.
(Chapter 1, section 1,2 of Text book 3).

Module 5. Some Global Results, Surfaces:Local Theory, Parametrized Surfaces and the First Funda- mental Form. (Chapter 1, section 3, Chapter 2, section 1 of Text book 3).

Semester V: Algebra: Groups and Rings

Course Code: MAM 10503
Course is to be taught in: V Semester Integrated

M. Sc. Number of credits:4

Total No. of Hours: 72 hours

Objective: Since groups are of great importance for the whole of mathematics, there is a highly developed theory of outstanding beauty. It takes just three simple axioms to define a group, and it is fascinating how much can be deduced from so little. 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: On successful completion of this course students will have acquired

1. Asound understanding of the classification of finitely generated abelian groups.
2. knowledge of some fundamental results and techniques from the theory of finite groups.
3. an understanding of the symmetries in the Euclidean plane.

Prerequisites Set theory and numbers, the concept of groups, subgroups and various examples as given in an earlier semester.

Text books:

1John B. Fraleigh: *A First Course in Abstract Algebra*, 7th Edition, Pearson Education, 2006. 2Michael Artin: *Algebra*, Prentice-Hall India, New Delhi, 1994.

Reference books:

1. Thomas.W.Hungerford: *Algebra* , Springer, 1974.
2. I S Luther and I B S Passi: *Algebra Vol I*, Narosa Publishing House, 2013.
3. I S Luther and I B S Passi: *Algebra Vol II*, Narosa Publishing House, 2012.
4. Joseph A. Gallian: *Contemporary Abstract Algebra*, Nineth Edition, Cengage Learning, 2017.
5. M.A. Amstrong: *Groups and Symmetry*, Springer, 1988.
6. I.N.Herstein: *Topics in Algebra*, 2nd Edition, John Wiley & Sons,
7. N. S. Gopalakrishnan: *University Algebra*, 2nd Edition), New Age International, 1986.

Syllabus

Module 1. Review of group theory: Groups, Subgroups, Cyclic groups, Generating sets. (Section 4,5,6,7 of of Text Book 1). Groups of Permutations, Orbits, Cycles, Alternating Groups, Cosets and Theorem of Lagrange. (Section 8,9,10 of Text Book 1).

Module 2. Direct Products and Finitely Generated Abelian Groups, Homomorphisms, Factor Groups, Factor-Group Computations and Simple Groups (Section 11,13,14,15 of Text Book 1).

Module 3. Symmetry: Symmetry of plane figures, The group of motions of the Plane, Finite group of motions (Section 5.1, Section 5.2, and Section 5.3 of Text Book 2).

Module 4. Introduction to Rings and Fields,Integral Domains, Fermat's and Euler theorems, The field of quotients of an integral domain. (Section 18, 19, 20, 21 of Text Book 1).

Module 5. Rings of Polynomials, Factorization of polynomials over a field, Homomorphisms and factor rings, Prime and Maximal ideals. (Section 22, 23, 26, 27 of Text Book 1).

Semester V: Introduction to Complex Analysis

Course Code: MAM 10504

Course is to be taught in: V Semester Integrated

M. Sc. Number of credits: 4

Total No. of Hours: 72 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 equipped with the understanding of the fundamental concepts of complex variable theory and its application

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.

Syllabus

Module 1. Review of Complex numbers Chapter - I, Functions of Complex Variable, Mappings, Mappings by the Exponential Function, Limits, Theorems of Limits, Limits Involving the Point at Infinity, Continuity, Derivatives and Differentiation Formulas. (Sections 12, 13, 14, 15, 16, 17, 18,19, and 20 of the Text book 1).

Module 2. Cauchy-Riemann Equations, Sufficient Conditions for Differentiability, Polar Coordinates, Analytic Functions, Examples and Harmonic Functions. (Sections 21, 22, 23, 24, 25, and 26 of the text book 1).

Module 3. The Exponential Function, The Logarithmic Function, Branches and Derivatives of Loga- rithms, Some Identities Involving Logarithms, Complex Exponents, Trigonometric Functions Hyper- bolic Functions, Inverse Trigonometric and Hyperbolic Functions. (Sections 29, 30, 31, 32, 33, 34, 35, and 36. of the text book 1).

Module 4. 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 37, 38, 39, 40, 41 43, 44, and 46 of the text book 1).

Module 5. Cauchy Integral Formula, An Extension of the Cauchy Integral Formula, Some Conse- quences of the Extension, Liouville’s Theorem and the Fundamental Theorem of Algebra, Maximum Modulus Principle. Convergence of Sequences, Convergence of Series, Taylor Series, Examples, Laurent Series, and Examples. (Sections 50, 51, 52, 53 and 54 55, 56, 57, 59, 60 and 62 of the text book 1).

<u>Semester VI: Analysis II</u>

Course Code: MAM 10601

Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 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 aware of doing calculus on the real line, capable of understanding the calculus on the n-dimensional Euclidean space and the integration.

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. (Sec- tions 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).

Objective: This course introduces the developments of ordinary and partial differential equations.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of ordinary and partial differential equations.

Prerequisites Basic Calculus and linear algebra.

Text books:

1. George F. Simmons, Differential Equations with Applications and Historical Notes, Tata McGraw-Hill Second Editon 2003.

2. Walter A. Strauss, Partial Differential Equations an Introduction, John Wiley, 1992.

Reference books:

(1) S. L Ross, Differential Equations, Wiley.

(2) W.E Boyce and R. C. DiPrima, Elementary Differential equations and Boundary Value Problems, John Wiley & Sons, 2001.

(3) E. A. Coddington, An Introduction to Ordinary Differential Equations, Dover, 1989.

Syllabus

Module 1. Oscillations and the Sturm Separation Theorem, The Sturm Comparison Theorem, Series solutions of First order equations. (Chapter 4 and sections 25, 26 of chapter 5 (Text book 1)

Module 2. Legendre Polynomials, Properties of Legendre Polynomials, Bessel functions. The Gamma Function, Properties of Bessel functions. (Chapter 6 of text book 1).

Module 3. The method of Successive Approximations, Picard's Theorem, Systems. (Chapter 11 of text book 1).

Module 4. What Is a Partial Differential Equation?, First-Order Linear Equations, Flows, Vibrations, and Diffusions, Initial and Boundary Conditions, Well-Posed Problems. (Sections 1.1, 1.2, 1.3, 1.4 and 1.5 of text book 2).

Module 5. The Wave Equation, Causality and Energy, The Diffusion Equation, Diffusion on the Whole Line, Comparison of Waves and Diffusions. (Sections 2.1, 2.2, 2.3, 2.4 and 2.5 of text book 2).

Objective: This course introduces the concepts and results from complex variable theory and Number theory that are required for further study of advanced mathematics. 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 with the understanding of the fundamental concepts of complex variable theory, Number theory and its application.

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).
2. G. A. Jones and J. M. Jones, Elementary Number Theory, Springer-Verlag (1998).

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. Ivan Niven, Herbert S. Zuckerman, and Huge L. Montgomery: An Introduction to the Theory of Numbers, 5th Edition., John Wiley & Sons, Inc., New York, (1991).

Syllabus

Module 1. 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 (Sections 63, 64, 65, 66, 67, 68 and 69 of Text book 1).

Module 2. Cauchy's Residue Theorem, Residue at Infinity, 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: 71, 72, 73, 74, 75, 76 and 77 of Text book 1).

Module 3. Evaluation of Improper Integrals, Example, Improper Integrals from Fourier Analysis, Jordan's Lemma, Indented Paths, An Indentation Around a Branch Point, Integration Along a Branch Cut, Definite Integrals Involving Sines and Cosines, Argument Principle, Rouche's Theorem, Inverse Laplace Transforms and Examples. (Sections: 78, 79, 80, 81, 82, 83, 84, 85, 86, 87 and 88 of Text book 1).

Module 4. Divisors, Bezout's identity, Least common multiples, Linear Diophantine equations, Prime Numbers, Prime numbers and prime-power factorisations, Distribution of primes, Fermat and Mersenne primes, Primality-testing and factorisation. (Chapter 1 and 2 of Text book 2).

Module 5. Modular arithmetic, Linear congruences, Simultaneous linear congruences, Simultaneous non-linear congruences, An extension of the Chinese Remainder Theorem.
(Chapter 3 of Text book 2).

Objective: This course gives a thorough introduction to Discrete Mathematics with rigorous Mathe- matics and serves as the basis for further studies in this area.

Outcome: After completing the course, the student will achieve a basic foundation in Discrete Math- ematics.

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. Eu- ler'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 (algo- rithm 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 func- tions.
Text 2: Chapter 15 (Sections 15.1-15.11)

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 stu- dent 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:

1. Solve LP problems geometrically and more effectively using Simplex algorithm.
2. Understand duality theory, a theory that establishes relationships between linear programming problems of maximization and minimization.
3. Solve transportation and assignment.
4. Determine the shortest path, critical path and maximal flow in a network.

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 Mathe-matics 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 VI: Elements of Applied Mathematics (Elective - III)

Course Code: MAM 10606

Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course starts with the structure of 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 be familiar with the necessary tools in applied mathematics in a signal processing perspective.

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 NewYork, (1999).
2. Walter G. Kelley & Allan C. Peterson Difference Equations An Introduction with Applica-ions, 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, Generat- ing 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 VI: Introduction to Optimization Techniques (Elective - IV)

Course Code: MAM 10607

Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 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 uncon- strained optimization problems.

Learning Outcomes: After the completion of this course, the student should be able to

1. Classify optimization problems based on objective function, constraints.
2. Use the knowledge of different optimization methods to solve an optimization problem efficiently.

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 Opti- mization 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, New- ton'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 Program- ming. Problem. (Sec 7.9-7.8, 7.10-7.15).

Semester VI : Metric Topology (Elective - V)

Course Code: MAM 10608
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 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 become familiar with metric topol- ogy, so that it will become easy for the students to learn general topology course in forthcoming semesters.

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, Uni- form 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, Charac- terization 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 VI : Fuzzy Mathematics (Elective - VI)

Course Code: MAM 10609
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 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: The student will achieve a basic foundation in Fuzzy Mathematics which is one of the best tools to create mathematical models, as real life examples are more fuzzy in nature than being crisp.

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 Pub- lishing Company 1986.

Syllabus

Module 1: Crisp sets to Fuzzy sets

Introduction , Crisp Sets: An Overview ,Fuzzy Sets: Basic Types ,Fuzzy Sets: Basic concepts. Addi- tional 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).

5 Year Integrated M.Sc. Program in Science Mathematics Course

Syllabus

(Last 4 Semesters)

Admission from 2021 Batch Onwards

Syllabus for MSC 2021 Admissions Onwards

MAM 10701 LINEAR ALGEBRA

Credits: 4

Total No. of Hours: 72

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

(1) have a clear understanding of vector spaces, linear transformations, coordinates and the representation of transformation by matrices.
(2) have a knowledge of the dual space of a vector space and importantly we also introduce the notion of the adjoint of a linear map which acts between the dual spaces.
(3) understand the important generalization of the notion of linear maps to more than one variable. In particular the multi-linear Determinant map and its important properties are studied in details.
(4) achieve ideas on the advanced topics like annihilating polynomials, simultaneous triangulation and diagonalization and direct sum decomposition.
(5) have knowledge on primary decompositions associated with subspaces or with respect to a given operator.

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).

MAM 10702 REAL ANALYSIS **Credits: 4**

Total No. of Hours: 72

Objective: This course starts with the structure of Real Numbers. This course is planned to intro- duce 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: This course is planned to build up calculus and other important notions on the set of real numbers. After the completion of this course, the student should able to be familiar with 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.

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 con- tinuity, 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. 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).

MAM 10703 MEASURE AND INTEGRATION

Total No. of Hours: 72 **Credits: 4**

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

(1) be familiar with Lebesgue measure, General measure spaces.
(2) be familiar with the new tools of integration of measurable functions.

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, Charac- terizations 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. 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).

MAM 10704 - GROUPS AND RINGS

Total No. of Hours: 72 **Credits: 4**

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

- have a working knowledge of the concepts such as definition of a group, order of a finite group and order of an element.
- have a clear understanding of different types of subgroups such as normal subgroups, cyclic subgroups, and understand the structure of the structure of these subgroups
- will be able to understand the mathematical concepts such as permutation groups, factor groups, group homomorphisms etc.
- will have knowledge on advanced topics such as Sylow's theorem and should be able to apply this result.
- will be able to understand other mathematical structures such as rings and various classes of rings, their sub structures ideals, and their homomorphisms.

UNIT 1: Introduction to Groups: Basic Axioms and Examples, Dihedral Groups, Symmetric Groups, Matrix Groups, The Quaternion Group, Homomorphisms and Isomorphisms, Subgroups: Definitions and Examples, Centralizers and Normalizers, Stabilizers and Kernels, Cyclic groups, Groups gener- ated by subsets of a Group.

UNIT 2: Quotient Groups and Homomorphisms: Quotient Groups, homomorphisms, Langange's Theorem, The Isomorphism Theorems, Composition Series and Holder Program, Transpositions and Alternating Group

UNIT 3: Group Actions: Group actions and permutation representations, Cayley's Theorem, Orbits, Counting Lemma, Class Equation, Automorphisms, Sylow Theorems, Simplicity of A_n.

UNIT 4: Rings : Definition, Examples, Rings of Continuous Functions, Matrix Rings, Polynomial Rings, Power series rings, Laurent Rings, Boolean Rings, Direct Products, Several Variables, Char- acteristic of a ring.

Ideals: Definitions, Maximal ideals, generators, basic properties of ideals, algebra of ideals, quotient rings, ideals in quotient rings, local rings.

UNIT 5: Homomorphisms of rings: Definitions and basic properties, fundamental theorems, endo- morphism rings, field of fractions, prime fields.

Factorisation in domains: Division in domains, Euclidean domain, Principal ideal domains, factori- sation domains, Unique factorisation domains, Eisenstein's criterion.

Text Books:

(1) Abstract Algebra - D.S. Dummit and R.M. Foote, 3rd Edition, Publisher: Wiley.

(2) Rings and Modules - C. Musili, Second revised edition, Narosa Publishing House.

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.

MAM 10705 COMPUTATIONAL MATHEMATICAL LABORATORY

Total No. of Hours: 72 **Credits: 4**

Objective: This course starts with the review of Numerical methods for differentiation and integra- tion, 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 Be famil- iar with the skill to prepare mathematical documnets in LATEX and python programming techniques which are focused to be applied in mathematical problems.

UNIT 1: Introduction to LATEX Documentation setting, Standard document classes, Bibtex, standard environments, Macros, Table of contents, Bibliography styles, tables, Pstricks, Multiline math dis- plays (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, S pringer(2012).
4. John M. Zelle, Python Programming: An Introduction to Computer Science, (2002).
5. Steven Lott, F*unctional 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.

MAM 10801 FIELDS AND MODULES

Credits: 4

Total No. of Hours: 72

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

(1)have a working knowledge of the advanced concepts of group theory such as direct products, semi-direct products.

(2)should be able to classify the groups of small orders using the advanced concepts such as semi-direct products and direct products.

(3)understand the concept of algebraic structures called modules and recognize various types of modules.

(4)use the terminology and concepts of Field theory and apply those in a problem-solving approach.

(5) to apply the group-theoretic information to deduce results about fields and polynomials.

UNIT 1: Direct and Semi-direct Products and Abelian Groups: Direct products, Fundamental theorem of finitely generated abelian groups, Groups of small order, Recognizing direct products, Semi-direct Products.

UNIT 2: $p-$groups, nilpotent groups, solvable groups, applications in groups of medium order, free groups.

UNIT 3: Modules: Definitions and Examples, direct sums, free modules, vector spaces, quotient modules, homomorphisms, simple modules, modules over PID's.

UNIT 4: Fields: Irreducible polynomials, Classical Formulas, Splitting Fields, Finite fields, The Galois group, roots of unity, solvability by radicals.

UNIT 5: Fields: Independence of characters, Galois extensions, The fundamental theorem of Galois theory, Applications.

Text Books:

(1) Abstract Algebra - D.S. Dummit and R.M. Foote, 3rd Edition, Publisher: Wiley.

(2) Rings and Modules - C. Musili, Second revised edition, Narosa Publishing House.

(3) Galois Theory - J. Rotman, Second Edition, Springer International Edition.

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

MAM 10802 FUNCTIONAL ANALYSIS **Credits: 4**

Total No. of Hours: 72

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 be familiar with the concepts of Banach spaces, Hilbert spaces and operators acting on them.

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).

MAM 10803 COMPLEX ANALYSIS **Credits: 4**

Total No. of Hours: 72

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

1. be familiar with the Conformal mapping, Linear transformations, Analytic functions and the classical results in this regard.
2. use the results like residue theorems to compute integrals and apply to various fields.

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.

MAM 10804 TOPOLOGY I **Credits: 4**

Total No. of Hours: 72

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

1) understand topological properties
2) understand the connection of topology with other branches of mathematics
3) apply topological properties to prove theorems.

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).

MAM 10805 FUNCTIONS OF SEVERAL VARIABLES AND GEOMETRY

Credits: 4

Total No. of Hours: 72

Objective: In the first module, the students will be introduced to multivariable functions in Euclidean spaces and the notion of differentiation. The second module is aimed to apply the notions of multi-variable differentiation and associated local properties to regular curves and surfaces. Differentiable manifolds are introduced in the third module. In the fourth module the notions of geometry are introduced. The Riemannian metric structure on a differentiable manifold is introduced for conceptual clarity. The first fundamental form on regular surfaces is introduced first, after which comes orientation and the Gauss map. The Gauss map for regular surfaces is studied in details culminating in the concept of Gaussian curvature along with applications of the Gauss-Bonnet theorem. Finally the standard concepts in geometry of parallel transport, geodesics and the exponential map are also studied.

Learning Outcomes: After completion of this course, the students shall learn

(1) Have a clear understanding about continuity and differentiability of functions of several variables and their applications.
(2) Application of these concepts to regular curves and surfaces in Euclidean spaces.
(3) Develop understanding of tangent planes to regular surfaces and then differentiable manifolds are introduced.
(4) Different examples of manifolds, the concept of orientation and vector fields on such mani- folds are studied.
(5) Riemannian structure on a differentiable manifold is introduced which makes the study of geometry on regular surfaces in R3 more clear conceptually.
(6) Special emphasis is laid on the study of the Gauss map culminating with the Gaussian curvature for regular surfaces in R3. Gauss-Bonnet theorem and its applications are studied in details.
(7) Other important geometric concepts that are studied include the first fundamental form, par- allel transport, geodesics and the exponential map.

Pre-requisites:

(1)Basic real analysis and Linear Algebra

UNIT 1: Norm and inner product, subsets of Euclidean spaces, functions and continuity, (Differentia- tion in several variables), Basic definitions, basic theorems, partial derivatives, derivatives. (Relevant sections from chapters 1, 2 of textbook 1)

UNIT 2: Inverse functions, Implicit functions (Chapter 2 of textbook 1), 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 2).

UNIT 3: 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 3).

UNIT 4: Introduction to Riemannian metrics, Riemannian metrics (Chapter 1 of textbook 3), The

first fundamental form (Area), Orientation of Surfaces, The definition of the Gauss map and its fundamental properties, The Gauss map in local coordinates. (Sections 2.5, 2.6, 3.2, 3.3 of textbook 2).
UNIT 5: The Gauss theorem and the equations of compatibility, Parallel transport, Geodesics, The Gauss-Bonnet theorem and its applications, The exponential map, Geodesic polar coordinates. (Sections 4.3, 4.4, 4.5, 4.6 of textbook 2).

Text Book:

(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.

MAM 10901 OPERATOR THEORY **Credits: 4**

Total No. of Hours: 72

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 be familiar with the spectral theory of compact self-adjoint operators and its applications.
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 Prob- lems. (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).

MAM 10902 TOPOLOGY II

Total No. of Hours: 72 **Credits: 4**

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 shall learn

(1) About nets and filters, the generalisation of sequences for topologies that are no more defined by a metric.
(2) The important geometric objects like complexes and Polyhedra and different identification spaces whose topology is studied.
(3) The definition of simplicial homology groups and their application to compute the homology groups for certain important spaces.
(4) The fundamental group and the Van Kampen theorem with examples.
(5) Covering spaces their properties along with their classification.

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, Pseudo-manifolds 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

Reference

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.
4. J. R. Munkers: Topology (Second Edition) PHI, 2009.
5. Massey W.S.: Algebraic Topology : An Introduction, Springer Verlag NY, 1977 (7)S.T. Hu: Homology Theory, Holden-Day, 1965

MAM 10903 Ordinary Differential Equations & Integral Equations

Credits: 4

Total No. of Hours: 72

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: Students will be able to understand the popular mathematical models of real life problems in terms of ordinary differential equations and Integral equations.

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 Equa- tion. (Chapter 4, Section 24, 25. Chapter 5, sections 27, 28, 29, 30, 31.)

UNIT 2: Legendre Polynomials, Properties of Legendre Polynomials, Bessel Polynomials, Proper- ties 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 Differ- ential 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 Me- dia, 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).

MAM 10904: Probability Theory **Credits: 4**

Total No. of Hours: 72

Objective: This course starts with the introduction to probability theory following different probabil- ity 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

(1)be familiar with the concepts of probability theory and classical results.

(2)use the terminology and concepts of probability theory and apply those in a problem-solving approach.

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 condition- ing, 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 Theo- rem, 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.

MAM 11001 PARTIAL DIFFERENTIAL EQUATIONS & VARIATIONAL CALCULUS.

Credits: 4

Total No. of Hours: 72

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 be familiar with the concepts of classical models of diffusion and wave phenomena. Able to use the terminology and concepts of PDE's and apply those in a problem-solving approach.

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).

MAM 10905 TOPICS IN APPLIED MATHEMATICS **Credits: 3**

Total No. of Hours: 54

Objective: To Learn important Mathematical Tools applicable in Science and Technology.

Learning Outcomes: After the completion of this course, the student should able to be

(1) familiar with the necessary mathematical tools that are used in science and technology.
(2) failiar with the popular transforms of Laplace and Fourier and their applications to various fields.
(3) familiar with the popular mathematical models like vibating string, Heat conduction etc. and its solution using transforms.
(4) familiar with the necessary machinery in complex function theory.

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 Deriva- tives 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 equa- tions, 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.

MAM 11002 WAVELETS **Credits: 4**

Total No. of Hours: 72

Objective: This course starts with the structure of C*n*. This course is planned to introduce the Wavelets as an extension to the idea of Fourier's method in Linear algebraic perspective.

Learning Outcomes: After the completion of this course, the student should be able to be familiar with Multi-resolution analysis and its applications in different contexts like the space of periodic functions, non-periodic functions and on the space of square integrable functions on the real line.

UNIT 1: The Discrete Fourier Transform, Translation-Invariant Linear Transformations, First Stage Construction of Wavelets on Z_N (Chapter 2, Chapter 3, Sections 2.1, 2.2, 3.1)

UNIT 2: Construction of Wavelets on Z_N : Iteration step, Examples and Applications, $l^2(Z)$ (Chapter3, 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 $l^2(Z)$(Chapter 4, Sections 4.2, 4.3, 4.4, 4.5)

UNIT 4: First-Stage Wavelets on Z*,* The Iteration step for Wavelets on Z*,* Implementation and Examples. (Chapter 4, Sections 4.6, 4.7, Chapter 5, Section 5.1,)

UNIT 5: L^2(R) and approximate Identities, The Fourier Transform on 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).

MAM 11003 Optimization and Mathematical Methods for Deep Learning

Credits: 4

Total No. of Hours: 72

Objective: The objective of this course is

(1) to introduce optimization and discuss mathematical methods behind deep learning process.
(2) to give an insight on the mathematical tools and techniques required for modelling real life problems related to deep learning process.
(3) to provide the basis idea of convex analysis.

Learning Outcomes: After the completion of this course, the student will

(1) learn about the different types of optimization problems.
(2) acquire knowledge on mathematical models in Deep Learning process through linear algebra, Basic Probability theory, Optimization techniques, Neural Network and Fuzzy Logic and fuzzy systems.
(3) understand the basic concepts behind convex optimization such as convex sets, convex functions, differentiable and non-differentiable convex functions, optimum of convex function, necessary and sufficient optimality conditions for constrained and unconstrained optimization problem.

UNIT 1: (Different types of optimization) (Text 4) Discrete and Continuous Optimization, Constrained and Unconstrained Optimization, Deterministic and Stochastic Optimization, Optimization with none, one or many objectives. Some Illustrative Examples: Optimal Control Problems, Electrical Networks, Water Resources Management, Stochastic Resource Allocation, Location of Facilities. (Chapter 1)

UNIT 2: (Fuzzy Sets & Systems) (Text 3) Basic Definition and Terminology, Set-theoretic Operations, Member Function, Formulation and Parameterization, Fuzzy rules and fuzzy Reasoning, Extension Principal and Fuzzy Relations, Fuzzy if-then Rules, Fuzzy Inference Systems, Implementation using MATLAB.

UNIT 3: (Basics in Deep Learning) (Text 2) History of Deep Learning, Mc Culloch Pitts Neuron, Perceptron, Perceptron Learning Algorithm, MLP, Sigmoid Neurons, Gradient Descent, Feedforward Neural Networks, Back propagation Algorithm; Implementation using MATLAB.

UNIT 4: (Some Learning Strategies and Modern Trends in Deep Learning) (Text 1 & 2) Learn- ing Theory, Supervised and Unsupervised Learning; Regression- Ordinary Least Squares, Polyno- mial Regression, Classification- Nearest Neighbour Model; Linear Discriminant Analysis, Quadratic Discriminant Analysis; Clustering- Dimensionality Reduction, K- Means Clustering. (Text 1) Convolution Neural Network (CNN), Recurrent Neural network (RNN), Auto encoders. (Text 2)

UNIT 5: (Basics of Convex Analysis) (Text 4) Convex sets, Convex hull, Closure and interior of a set, Weierstrass theorem, Separation and support of sets, Convex cones and polarity. (Chapter 2: 2.1-2.5) Convex functions and basic properties, Subgradients of convex functions, Differentiable convex functions, minima and maxima of convex functions. (Chapter 3: 3.1-3.4) The Fritz john and Karush-Kuhn-Tucker Optimality Conditions (without proofs). (Chapter 4: 4.1-4.3)

Text Books:

(1) T. M. Mitchell, “Machine Learning”, McGraw Hill, 2017.
(2) Deep Learning, Ian Goodfellow and YoshuaBengio and Aaron Courville, MIT Press, 2016.
(3) Bo Yuan, George J. Klir, “Fuzzy Sets and Fuzzy Logic: Theory and Applications”, Pearson Publishers, Second Edition 2015.
(4) M. S. Bazaraa, Hanif D. Sherali, C. M. Shetty; “Nonlinear Programming theory and algo- rithms”. John Wiley & Sons, Inc. Second Edition 2004.

References:-

(1) S.N. Shivnandam, “Principle of soft computing”, Wiley.
(2) Timothy J.Ross, “Fuzzy logic with Engineering Applications”, McGraw-Hills
(3) Jack M. Zurada, “Introduction to Artificial Neural Network System” JAico Publication.
(4) Simon Haykins, “Neural Network- A Comprehensive Foudation”.
(5) Hans-Jurgen Zimmermann,” Fuzzy Set Theory - and its Applications” Second -Revised Edi- tion 2013, Springer Netherlands.
(6) Rao’s “Linear Statistical Inference and its Applications” published by Wiley ISBN: 978-0- 471-21875-3.
(7) Press, Teukolsky, Vetterling, & Flannery “Numerical Recipes: the Art of Scientic Computing” published by Cambridge University Press, ISBN: 978-0-521-88068-8.
(8) Horn & Johnson’s “Matrix Analysis” published by Cambridge University Press, ISBN: 978- 0-521-54823-6.
(9) Golub & Van Loan’s “Matrix Computations”, by Hopkins ISBN-13: 978-0801854149.
(10) Ross’ “A First Course in Probability”, published by Pearson, ISBN-13: 978-0321794772.
(11) Christopher Bishop’s “Pattern Recognition and Machine Learning” published by Springer, ISBN: 978-0-387-31073-2.
(12) R. T. Rockafellar “Convex Analysis” published by Princeton University Press, 1970.

MAM 11004 COMMUTATIVE ALGEBRA **Credits: 4**

Total No. of Hours: 72

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

(1) understand the basic definitions concerning different classes of commutative rings, elements in commutative rings, and ideals in commutative rings.
(2) know the theory of modules, including the tensor product of modules and algebras, and localisation.
(3) know the theory of primary decomposition of ideals in a commutative rings.
(4) know the theory of integral dependance and integral extensions.
(5) know the definition and examples of Noetherian and Artinian rings.

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 un- der ring homomorphisms; prime avoidance.

UNIT 2: Free modules; Projective Modules; Tensor Product of Modules and Algebras; Flat, Faith- fully 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 Ar- tinian 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).

MAM 11005 - GRAPH THEORY **Credits: 4**

Total No. of Hours: 72

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

(1) Understand the basic concepts of graph theory
(2) Have a clear picture of graph operators, graph parameters and graph classes
(3) Build graph models of real life problems
(4) Apply graph theoretic tools to solve problems.

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 –
1.1 (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, Match- ing 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)

MAM 11006 ADVANCED LINEAR ALGEBRA **Credits: 4**

Total No. of Hours: 72

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 familiar with the advanced concepts of linear algebra and matrix analysis. It is expected to develop the skills to deal with advanced techniques in estimating eigenvalues, singular values, etc.

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).

MAM 11007 DISCRETE FRAMELETS **Credits: 4**

Total No. of Hours: 72

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

(1) Understand the subject in a signal processing perspective with the help of finite filters.

(2) Be familiar with filterbank theory for signal analysis.

(3) Understand the multilevel framelet decomposition of signals in bounded intervals.

UNIT 1: Discrete Framelet Transform, Perfect reconstruction of discrete framelet transforms, One-Level Standard Discrete Framelet Transforms, Perfect Reconstruction of Discrete Framelet Trans-forms, 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 Poly-nomial Spaces, Subdivision Operator on Polynomial Spaces, Linear-Phase Moments and Symmetry Property of Filters, An Example. (Section 1.2 of text.)

forms, Stability of Multilevel Discrete Framelet Transforms, Discrete Affine Systems in A^2(Z), Non- **UNIT 3:** Multilevel Discrete Framelet Transforms and Stability, Multilevel Discrete Framelet Trans- stationary 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. (Sec- tion 1.4 of text.)

UNIT 5: Discrete Framelet Transforms for signals on bounded Intervals, Boundary Effect in a Stan-dard 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.

MAM 11008 HARMONIC ANALYSIS **Credits: 4**

Total No. of Hours: 72

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 Be familiar with the formulation of Measure and integration on Locally comopact groups and representations of Compact groups.

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 Com- pact 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).

MAM 11009 INTEGRAL TRANSFORMS **Credits: 4**

Total No. of Hours: 72

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 be familiar with popular integral transforms and its applications.
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,

- 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).

MAM 11010 FUNCTIONS OF SEVERAL VARIABLES **Credits: 4**

Total No. of Hours: 72

Objective: This course starts with the structure of R*n*. This course is planned to introduce the Differential calculus on the finite dimensional Euclidean Space and Integration on R*n*.
Learning Outcomes: After the completion of this course, the student should be able to be familiar with Differentiation and Intgration on R*n*.

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 R*n* to 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 R*n*, Riemann Integral of a bounded funtion on a compact interval in 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 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.

MAM 11011 ADVANCED SPECTRAL THEORY **Credits: 4**

Total No. of Hours: 72

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 be familiar with the properties and applications of spectrum and spectral theorem.

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, Hin- dusthan 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).

MAM 11012 BANACH ALGEBRAS AND SPECTRAL THEORY

Credits: 4

Total No. of Hours: 72

Objective: This course introduces the notion of Banach Algebras. The theory of commutative Ba- nach 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 become familiar with the fundamental concepts and applications of Banach Algebras and Spectral Theory.

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, Involu- tions, Positive functionals. (Chapter 11 of Text Book)

UNIT 3: Bounded Operators on a Hilbert Space: A commutativity theorem, Resolutions of the iden- tity, 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. Encyclopae- dia 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. Grad- uate Texts in Mathematics, 179. Springer-Verlag, New York, 1998.

MAM 11013 NUMBER THEORY **Credits: 4**

Total No. of Hours: 72

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 equa- tions.
Learning Outcomes: After the completion of this course, the student should be able to be famil- iar with divisibility, primes, congruences, the Chinese remainder theorem, quadratic reciprocity law, Arithmetic functions and diophantine equations.
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 East- ern, (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).

MAM 11014 REPRESENTATION THEORY OF FINITE GROUPS

Credits: 4

Total No. of Hours: 72

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: The leaner must have gained a proper understanding of the idea of group representations such as permutation representation, linear representations. The leaner will be capable of constructing the character table of some interesting class of groups.

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.

MAM 11015 ALGEBRAIC TOPOLOGY **Credits: 4**

Total No. of Hours: 72

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 comfortable with the nec- essary topological concepts and constructions like attaching spaces, suspension, excision, homotopy and deformation retraction among others. Along with the study of the fundamental group and classi- fication of covering spaces, the students will also work with the homology and cohomology theories, which will serve as an important application of their course in module theory.

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, Ex- act 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.

MAM 11016 DIFFERENTIAL GEOMETRY **Credits: 4**

Total No. of Hours: 72

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 (1)be familiar with the concepts vector fields, tangent space, surfaces and its orientations.

a get introduced to the spherical image of surfaces, geodesics, Weingarten map, and curvature of surfaces.

b understand local equivalence of surfaces and parametrized surfaces.

c obtain sound knowledge in rigid motions, congruence, isometries and results related these.

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.

DEPARTMENT OF PHYSICS

Scheme of Examinations and Syllabus for the Five Year Integrated M.Sc. Physics Degree Program

Approved by the Board of studies in Physics on 19th July 2021

(From 2021 admission onwards)

Cochin University of Science and TechnologyCochin - 682 022

Website: http://physics.cusat.ac.in

Preamble

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 build a strong foundation in science and technology.

The Department of Physics of Cochin University envisions carrying out this mission by providing qual- ity advanced training in Physics to students through its 5 year Integrated M.Sc. program and carrying out good scientific research. We strive to impart various skills to students, enabling them to take up scientific research and teaching as a career and engage in lifelong learning. We also acknowledge the diverse set of needs of students in a country like ours. We strive to impart to the students 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. Integrated M.Sc. students can access various research labs of the department, which further enhance their experience. We believe in moving with time and incorporate the latest trends and technological advancements in education. An increased focus on learning and using variouscomputational tools in the curriculum helps students progress in tune with the times.

Program specific outcomes: Integrated M.Sc. Physics

- Acquire mastery of several advanced topics in Physics according to the aptitude of students.
- Acquire excellent analytical and computational skills.
- Enable students to take up scientific research and teaching as a career and engage in lifelonglearning.
- Acquire firsthand experience in scientific research by working on research problems at the fore-front.
- Acquire excellent abilities in various aspects of scientific communication.

Table of Contents

Scheme

Semester – I

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
ENG 10101	English -I	C	50	50	100	2
MAL 10101	Malayalam - I*	C	50	50	100	2
HIN 10101	Hindi - I*	C	50	50	100	2
FLG 10101	Foreign Language - I* C		50	50	100	2

PHY10101	Mechanics	C	50	50	100	3
CHE 10101	Atomic Structure and Chemical Bonding	C	50	50	100	3
MAM 10101	Calculus - I	C	50	50	100	4
BTG 10101	Basic Principles of Biology	C	50	50	100	3
PHY 10102	Physics Lab - I (Mechanics)	C	100	–	100	2
CHE 10102	Chemistry Lab-I (Quantitative Analysis-I)	C	100	–	100	2
BTG 10102	Biology Lab - I (Basic Principles of Biology)	C	100	–	100	2
	Total		600	300	900	23

*Either Malayalam - I or Hindi - I or Foreign Language -I is to be opted.

Semester – II

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
ENG 10201	English -II	C	50	50	100	2
MAL 10201	Malayalam - II*	C	50	50	100	2
HIN 10201	Hindi - II*	C	50	50	100	2
FLG 10201	Foreign Language - II*	C	50	50	100	2
PHY 10201	Waves and Optics	C	50	50	100	3
CHE 10201	Periodicity, Nuclear Chemistry, Acid Base Chemistry and Metallurgy	C	50	50	100	3
MAM 10201	Linear Algebra and Graph Theory	C	50	50	100	4
BTG 10201	Biomolecules of Life	C	50	50	100	3
PHY 10202	Physics Lab - II (Waves and Optics)	C	100	–	100	2
CHE 10202	Chemistry Lab-II (Qualitative Analysis I)	C	100	–	100	2
BTG 10202	Biology Lab - II (Biomolecules of life)	C	100	–	100	2
	Total		600	300	900	23

Either Malayalam - II or Hindi - II or Foreign Language -II is to be opted.

Semester – III

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 10301	Electricity and Magnetism - I	C	50	50	100	3
CHE 10301	Introductory Organic Chemistry	C	50	50	100	3
MAM 10301	Calculus - II	C	50	50	100	4
MAM 10302	Mathematical Methods - I	C	50	50	100	4
BTG 10301	Introduction to cell biology and signaling	C	50	50	100	3
ENV 10301	Environmental Science	C	50	50	100	2
PHY 10302	Physics Lab - III (Electricity and Magnetism)	C	100	–	100	2
CHE 10302	Chemistry Lab-III (Qualitative analysis II)	C	100	–	100	2
BTG 10302	Biology Lab - III (Cell biology and signaling)	C	100	–	100	2
	Total		600	300	900	25

Semester – IV

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 10401	Quantum Physics and Relativity	C	50	50	100	3
CHE 10401	Introductory Physical Chemistry	C	50	50	100	3
MAM 10401	Mathematical Methods - II	C	50	50	100	3
STA 10401	Statistics and Probability	C	50	50	100	3
BTG 10401	Fundamentals of molecular Biology and Genetics	C	50	50	100	3
COM 10401	Basic Computer Science	C	50	50	100	2
PHY 10402	Physics Lab - IV (Modern Physics)	C	100	–	100	2
CHE 10402	Chemistry Lab - IV (Physical Chemistry)	C	100	–	100	2
BTG 10402	Biology Lab - IV (Molecular Biology and Genetics)	C	100	–	100	2
	Total		600	300	900	23

Semester – V

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 10501	Thermal Physics	C	50	50	100	4
PHY 10502	Electricity and Magnetism - II	CC	50	50	100	4
PHY 10503	Basic Mathematical Physics		50	50	100	4
PHY 10504	Basic Solid State Physics	C	50	50	100	4
PHY 10505	Physics Lab - V (Computer Lab)		100	–	100	4
	Total		300	200	500	20

Semester – VI

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 10601	Modern Optics	C	50	50	100	4
PHY 10602	Electronics	C	50	50	100	4
PHY 10603	Basic Nuclear Physics	C	50	50	100	4
PHY 10604	Minor Project	C	50	50	100	4
PHY 10605	Physics Lab - VI	C	100	–	100	4
	Total		300	200	500	20

Semester – VII

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 10701	Mathematical Physics	C	50	50	100	4
PHY 10702	Classical Mechanics	C	50	50	100	4
PHY 10703	Electrodynamics	C	50	50	100	4
PHY 10704	Quantum Mechanics – I	C	50	50	100	4
PHY 10705	Advanced Experiments in Physics Lab-I	C	100	-	100	3
	Total		300	200	500	19

Semester –VIII

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 10801	Quantum Mechanics – II	C	50	50	100	4
PHY 10802	Statistical Mechanics	CC	50	50	100	4
PHY 10803	Atomic and Molecular Spectroscopy	CC	50	50	100	4
PHY 10804	Advanced Electronics		50	50	100	4
PHY 10805	Advanced Experiments in Physics Lab-II		100	-	100	3
	Total		300	200	500	19

Semester – IX

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 10901	Nuclear and Particle Physics	C	50	50	100	4
PHY 10902	Advanced Solid State Physics	C	50	50	100	4
PHY 109*xx*	Elective – I	E	50	50	100	4
PHY 109*yy*	Elective – II	IE	50	50	100	4
PHY 10903	Advanced Experiments in Physics Lab-III	C	100	-	100	4
	Total		300	200	500	20

Semester – X

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 11001	Major Project$^{@}$	C E	200	200	400	16
PHY 11002	Online course	E	50	-	50	2
PHY 110*zz*	Elective – III (Online Mode)		50	50	100	4
	Total		300	250	550	22

Total credit requirement for the Program: 214

There will be no end semester examination for the practical or lab courses and they will have only continuous evaluation.

Elective - I and Elective - III (Online mode) are Departmental elective courses. i.e offered by the faculty members of the Department. Elective – II is the interdepartmental elective (IE) course. Replace *xx*, *yy* and *zz* with selected elective course codes. Classes and continuous evaluation of Elective- III will be conducted fully in online mode so that students who do major project in other institutions have no difficulty attending it. The mode of end semester examination of Elective-III will be decidedby the Department Council before the examination.

@**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 centres like IUCAA, NPOL, ISRO, DRDO, IIEST, industrial organisation, 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 supervisorfrom 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 Headto 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 ofthe 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 theproject will be done in the Department by a committee appointed by the Department Council/Department Head.

Online course PHY 2402 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) The credit given by the department for such a course will be two (2 only) regardless of its duration.

(b) 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 lengthof the 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 first semester. The students are allowed to choose a course from this approved set only.

(c) Students may register and complete the online course at their convenience during the two year period of the program 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 (2 only) 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 informingthe council.

Syllabus

Semester I

PHY 10101: Mechanics

Credits: 3
Hours : 54 hours

Course Objective

This intends to develop the basics methods of analysing the mechanics of a system using the most fundamental rules of mechanics.

Course Outcome

1. Understand the, Newtons laws of motion, the most fundamental rule of Mechanics.
2. Enable the students to apply the Newtons law in order to analyse basic dynamics of physicalsystems.
3. Acquire the capacity to use the energy conservation principle to understand the dynamics of asystem.
4. Familiarise the rules of understanding the different properties of the material world, like elasticity,surface tension, etc.

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, BerkeleyPhysics 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). (Chapters1-14).
2. Mechanics, L.D. Landau and I.M. Lifshitz, 3rd edition, Elsevier (2007).
3. The Feynman Lectures on Physics Vol I, Narosa Publications (2003). (Chapters 1-25).

Semester II

PHY 10201: Waves and Optics

Credits: 3
Hours : 54 hours

Course Objective

To impart the basic properties of waves to understand different properties of light.

Course Outcome

:

1. Familiarise the terms wavelength, frequency, superposition of waves.
2. Familiarise the method of Fourier analysis to study the properties of wave
3. Familiarise the electromagnetic wave properties.
4. understand the methods reflection, refraction.

Module I Free oscillations of simple systems: Systems with one degree of freedom, linearity and the superposition principle, systems with two degrees of freedom, Beats.

Module II Review of periodic motion, Representations of periodic motion-Free oscillations of simple systems: Systems with one degree of freedom, linearity and the superposition principle, systems with two degrees of freedom, Matrix method of finding the normal co-ordinates, Beats, Lissajous figures, Comparison of parallel and perpendicular superposition.

Module III Electromagnetic theory, Photons and Light: Basic laws, electromagnetic waves, energy and momentum, light in bulk matter, electromagnetic-photon spectrum. Rayleigh scattering.

Module IV Reflection, refraction, Fermat's principle, total internal reflection, Fiber optics, optical properties of metals, Familiar aspects of interaction of light with matter, The Stokes treatment of reflection and refraction.

Text Book:

1. Waves, F.S. Crawford Jr, Berkeley Physics Course Volume 3, Tata McGraw-Hill Ltd (2008).(Chapters 1-2).
2. A First course in Vibration and Waves, Mohammed Samiullah, Oxford University Press (2015)(Chapters 1-4)
3. Physics of Waves and Oscillations, H. J. Pain, Wiley (2005) (Chapter 10).
4. Vibration and Waves, The M.I.T Introductory Physics Series, A.P.French, W.W. Norton &Company (1971)
5. Optics, E. Hecht, 4th Edition, Pearson education (2009) (Chapters 3-5).

Reference Books:

1. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters15-16).
2. The Feynman Lectures on Physics Vol. I, Narosa (2003). (Chapters 26-36).

Semester III

PHY 10301: Electricity and Magnetism I

Credits: 3
Hours : 54 hours

Course Objective

:
This course will help in understanding basic concepts of electricity and magnetism and their applica-tions.
Basic course in electrostatics will equip the student with required prerequisites to understand electro-dynamics phenomena.

Course Outcome

:

1. Demonstrate Coulomb's law for the electric field, and apply it to systems of point charges.
2. Apply Gauss's law of electrostatics to solve a variety of problems.
3. Articulate knowledge of electric potential and electric potential energy and different electricalmeasuring instruments.
4. Demonstrate a working understanding of direct current circuits and characteristics of R- C andR-L circuits.
5. Describe the magnetic field produced by moving charge and various applications of motion ofcharged particles in the magnetic field.
6. Explain Faraday-Lenz laws to articulate the relationship between electric and magnetic fields.
7. Calculate the energy stored in a magnetic field

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.

Semester IV

PHY 10401: Quantum Physics and Relativity

Credits: 3
Hours : 54 hours

Course Objective

: The course aims to develop an understanding among the students about importance of Quantum Physics and Relativity. After completing this course, the students should be able to

1. Understand about special theory of relativity, doppler effect, time dilation, length contraction,relativistic energy and momentum.
2. Understand the importance of wave particle duality in blackbody radiation, photoelectric effect,Compton effect, pair production and particle in a box.
3. Describe the atomic structure and emission/absorption spectra.
4. Solve particle in a box, finite potential well, and harmonic oscillator problems using Schrödinger's equation.

Course Outcome

1. Solve standard problems in doppler effect, time dilation, and length contraction.
2. Define postulates of Special theory of relativity.
3. Understand the wave particle duality.
4. Understand the necessity of quantum physics for explaining blackbody radiation, photoelectriceffect, Compton effect.
5. Differentiate phase and group velocity of de Broglie waves.
6. Understand Bohr atom model and energy levels.
7. Calculate excitation wavelength corresponding to different atomic transition.
8. Differentiate the importance of 3 and 4 level lasers with its energy level diagram.
9. Solve particle in a box, finite potential well, and harmonic oscillator problems using Schrödinger's equation.

Module I The speed of light as a fundamental constant of nature, measuring speed of light, speed of light in inertial frames in relative motion, Doppler effect. Special theory of relativity: basic assump- tions, Lorentz transformation, time dilation and length contraction, relativistic energy and momen- tum, Transformation of momentum and energy, Transformation of the rate of change of momentum, constancy of charge, problems in relative dynamics.

Module II Particleproperties of waves: electromagnetic waves, blackbody radiation, photoelectric effect, X-rays, Compton effect, pair production. Wave properties of particles: De Broglie waves, phase and group velocities, particle diffraction, particle in a box, uncertainty principle.

Module III Atomic structure: Electron orbits, atomic spectra, The Bohr atom, Energy levels and spectra, nuclear motion, atomic excitation, laser.

Module IV Quantum mechanics: The wave equation, Schrödinger's equation, linearity and super- position, expectation values, operators, steady state equation, particle in a box, finite potential well, tunnel effect, harmonic oscillator.

Text Books:

1. Concepts of Modern Physics, Arthur Beiser, Tata McGraw-Hill, 7th Edition, (2015).
2. Quantum Physics, H. C. Verma, Surya Publications, 2nd Edition (2009).
3. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters37-44).

Reference Books:

1 physics, E.H. Wichmann, Berkeley Physics Course Volume 4, Tata Quantum McGraw-Hill Ltd(2008).

2 Introduction to Quantum Mechanics, D. Griffiths, 2nd Edition, Cambridge University (2017).

Semester V

PHY 10501: Thermal Physics

Credits: 4
Hours : 72 hours

Course Objectives

This course introduces basics of thermal physics to the students. The course aims to make the studentsunderstand and apply various concepts of thermodynamics.

Course Outcomes

Upon completion of this course, a student should be able to -

1 Demonstrate an understanding of the terminology, concepts and principles of thermal physics.

2 Develop basics of Kinetic theory of gases.

3 Demonstrate an understanding of basics of thermal transport.

4 Demonstrate an understanding of laws of Thermodynamics.

5 Demonstrate an understanding of various thermodynamic potentials and their uses.

Module I Introductory material: Heat and heat capacity, basic probability, thermal equilibrium. Kinetic theory of gases: Maxwell-Boltzmann distribution, Pressure, Molecular effusion, mean free pathand 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).

PHY 10502: Electricity and Magnetism II

Credits: 4
Hours : 72 hours

Course Objective

In paper I of this subject we have introduced the basic of electricity and magnetism. In this paper themain 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

1 Familiarise with the basics of electric field in conductors.

2 Familiarise with dielectric properties and allied phenomenon called electric polarisation.

3 Understanding mainly the alternating current and displacement current and their significance.

4 Understanding the magnetic properties of matter.

Module I Electric fields around conductors: Conductors and Insulators, Conductors in the Electro- static 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 Po- tential and Field of a Dipole, The Torque and the Force on a Dipole in an External Field, Atomicand 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 ina 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 Electromag- netic 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 andthe 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).

PHY 10503: Basic Mathematical Physics

Credits: 4
Hours : 72 hours

Module 1

Course Objectives

This course introduces basic mathematical tools used in physics to the students. The course aimsto prepare the students for understanding and applying various mathematical formalisms used in physics. The course is a very relevant one for students as the mathematical techniques introduced findapplications in every branch of physics and other quantitative sciences.

Course Outcomes

Upon completion of this course, a student should be able to -

1. Set up and solve problems involving matrices.
2. Diagonalize a matrix.
3. Solve basic problems in probability and understand Binomial and Poisson probability distribu-tions.
4. Understand and solve basic problems in sample statistics.
5. Solve first order ordinary differential equation by different techniques.
6. Demonstrate an understanding of Heaviside unit step function and Dirac delta function.
7. Demonstrate an understanding of Fourier series and its applications.
8. Find Fourier transform of function.
9. Find Laplace transform of functions.
10. Use Laplace transform to solve an ordinary differential equations with constant coefficients.

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 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.

Module III 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, miscellaneousequations. Higher degree first order equations.

Module IV Heaviside unit step function, one dimensional Dirac delta function, properties and representations, three dimensional Dirac delta function. Fourier series–general properties, applications and properties of Fourier series. 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.

Text Books:

1. Tai L. Chow, Mathematical Methods for Physicists. A concise introduction, Cambridge Univer-sity Press (2008).
2. George Arfken, Mathematical Methods for Physicists, Fourth (Prism Indian) 7th Edition, Else-vier (2012).
3. K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical methods for physics and engineering,Cambridge Universality Press (2006).

PHY 10504: Basic Solid State Physics

Credits: 4
Hours : 72 hours

Course Objective

Introduce the most basic structure of solid state physics.

Course Outcome

1. Understanding the various types crystal structure and their properties.
2. Understanding the band structure in crystals.
3. Understanding the magnetic properties of solids and also the fundamentals of superconductivity.

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).

Semester VI

PHY 10601: Modern Optics

Credits: 4
Hours : 72 hours

Course Objective

Light and its various properties are important to understand to use them for suitable application. The objective of this course is to help the students in this regard in the basic level.

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Course Outcome

1. Understanding the modulation of light and its various significance.
2. Familiarise with the most important property of light, the polarisation and its significance.
3. Understanding Interference and diffraction of light.
4. Understanding the basics of Fourier optics.

Module 1 Modulation, pulses and wave packets: Group velocity, pulses, Fourier analysis of pulses and traveling wave packet.

Module 2 Nature of polarized light, polarizers, dichroism, birefringence, scattering and polarization, polarization by reflection, retarders, circular polarizers, polarization of polychromatic light, optical activity, induced optical effects-optical modulators, liquid crystals

Module 3 Interference: General considerations, conditions for interference, interferometers, types and localization of interference fringes, multiple-beam interference, applications of single and multi-layer films, applications of interferometry. Diffraction: Fraunhofer diffraction, Fresnel diffraction.

Module 4 Fourier optics: Introduction, fourier transforms, optical applications. Basics of coherence theory, mutual coherence function and the degree of coherence, Lasers: Lasers and laser light, Imagery,holography, nonlinear optics (basics)

Text Books:

1. Waves, F.S. Crawford Jr, Berkeley Physics Course Volume 3, Tata McGraw-Hill Ltd (2008).(Chapters 6).
2. Optics, E. Hecht, 4th Edition, Pearson education (2009) (Chapters 8-13).

Reference Books:

1. Introduction to modern optics, G.R Fowls, Second edition, Dover (1989).
2. Optics, Ajoy Ghatak, 5 edition, McGraw Hill Education (2012).

PHY 10602: Electronics

Credits: 4
Hours : 72 hours

Course Objective

To teach the basics of electronics

Course Outcome

1. Familiarise with the principles and characteristics of diodes and transistors
2. Understanding the operations of different types of amplifiers.
3. Understanding the basics of the digital circuits.
4. Understanding about the logical gates and their practical significance.

Module I Diode theory, forward and reverse-biased junctions, reverse-bias breakdown, load line analysis, diode applications - Limiters, clippers, clampers, voltage multipliers, half wave & full wave rectification, Special purpose diodes - Zener diode, Varactor, light emitting diodes, Laser diodes, Transistor fundamentals, Review of the characteristics of transistor in CE and CB configurations, Regions of operation (active, cut off and saturation), Current gains α and β. Relations between $\alpha$and β, dc load line and Q point, Field-Effect Transistors (FET).

Module II Single and multi-stage transistor amplifiers, Concept of feedback, negative and positive feedback, Transistor oscillator circuits, Operational Amplifier basics, practical Op-Amp circuits, differential and Common mode operation, Inverting & Non Inverting Amplifier, differential and cascade amplifier, Op-Amp applications.

Module III Number System – Introduction to binary, octal, decimal & hexadecimal systems, representation of negative numbers, 1's, 2's, 9's, 10's complement and their arithmetic, Boolean algebra
– Boolean theorems, minimization of Boolean function, K-Map, minimization using tabular method.

Module IV Basic logic gates, Boolean functions realization using logic gates, half & full adder, subtracter, 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 Edu-cation (1994).

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. A. Anand Kumar, Fundamentals of Digital Circuits (3rd Edition), PHI Learning Pvt. Ltd., NewDelhi (2014).
5. R. P. Jain, Thomas L. Floyd, Digital Fundamentals, Pearson Education (2005).

PHY 10603: Basic Nuclear Physics

Credits: 4
Hours : 72 hours

Course Objective

This paper intends to extend the student the basic knowledge in Nuclear Physics

Course Outcome

:

1. Understanding the basic properties of atomic nucleus, binding energy and elements of nuclearmodels
2. Familiarise the fundamental rules radioactivity and also nuclear reaction rate
3. Understanding the radiation-matter interaction
4. Familiarise the basic principles of nuclear reactors.

Module I Introduction and Basic concepts: The nucleus and its constituents, the N-Z chart, Nuclear mass, Radius, Density, Spin, Parity, Magnetic and electric moments, Stable Nuclei, Binding energy, Nuclear potential and energy levels, Semi empirical (liquid drop) model, Fermi-gas model, Nuclear shell model (with the harmonic oscillator potential), spin-orbit coupling and magic numbers.

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.

Module III Interaction of radiation with matter: Heavy charged particles interactions, Bethe-Bloch formula, Energy dependence, Bragg curve, Projectile dependence, Stopping medium dependence, Ab- sorbed dose, equivalent dose, Gamma rays interactions, photoelectric effect, Compton scattering, Pairproduction, Attenuation.

Module IV Linear and circular accelerators, Nuclear reactors and energy production, Breeder reactors, Applications in tracing, material modification, sterilization, material modification, neutron activation analysis, Diagnostic Nuclear Medicine and Therapeutic Nuclear Medicines: CT, PET, SPECT, MRI.

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).

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).

Semester VII

PHY 10701: Mathematical Physics

Credits: 4
Hours : 72

Course Objectives

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 used in physics. 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 Outcomes

Upon completion of this course, a student should be able to -

1 Demonstrate an understanding of the meaning of gradient, divergence and curl. Work with themin different coordinate systems, and solve problems involving scalar and vector fields.

2 Demonstrate an understanding of basic tensor analysis.

3 Solve problems involving calculus of functions of a complex variable.

4 Solve a second order linear differential equation.

5 Solve important partial differential equations such as Laplace equation, wave equation and Pois-son equation by the method of separation of variables.

6 Solve an equation numerically.

7 Solve differential equations numerically.

8 Calculate definite integrals numerically.

9 Solve basic problems in probability and demonstrate an understanding of the Binomial, Poissonand Gaussian probability distributions.

Module I

Review of vector calculus. Orthogonal curvilinear coordinates, cylindrical and spherical polar coordi- nates. 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 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).

PHY 10702: Classical Mechanics

Credits: 4
Hours : 72 hours

Course Objectives

The course aims to develop an understanding of Lagrangian and Hamiltonian formulation which enable 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, 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.
- To explain generating function, canonical transformation & Poisson brackets.
- 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 Outcomes

1. 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)
2. Understanding the Hamiltonian formalism in solving physics problems and understand Poisson bracket method in tackling physical problems. (Module 2)
3. Understanding the techniques for solving the problems of rigid body mechanics based on Lagrange's formulation (Module 3)
4. Understanding the Hamiltonian-Jacobi formulation and it's applications, solving simple problems based on action-angle variables. Understanding the basic features of non-linear dynamics (Module 4)

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 equationsform it. Symmetry properties and Noether's theorem. Application of Lagranges equation to Central force problem - equivalent one dimensional problem - classification of orbits - the differential equationfor orbits - Kepler problem.

Module II - Hamiltonian Mechanics

Derivation of Hamilton's equation form 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 co-ordinates 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

Chaotic trajectories and Liapunov exponents. Poincare maps. Logistic maps. Bifurcations, driven damped harmonic oscillator, parametric resonance. Logistic equation. Fractals and dimensionality : Cantor set, Sierpinski carpet.

Text Books:

1. H. Goldstein, C. Poole and J. Safko , Classical Mechanics, Third Edition, Pearson (2011).
2. N. C. Rana and P.S. Joag: Classical Mechanics, TMH, 1994
3. Michael Tabor, Chaos and Integrability in Nonlinear Dynamics, Wiley (1989).

Reference Books:

1. V. B. Bhatia , Classical Mechanics, Narosa (1997).
2. Landau and Lifshitz, Mechanics Vol. I, 3rd Edition, Butterworth-Heinemann (1976).

PHY 10703: Electrodynamics

Credits: 4
Hours : 72 hours

Course Objectives

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, conservationlaws and boundary conditions of electromagnetic fields at an interface.
- Application of Maxwell's equations for the study of propagation of electromagnetic waves invarious 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 ofrelativity.

Course Outcomes

1 Will get familiarized with the various boundary value problems and learn different techniquesfor its solutions (Module 1).

2 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).

3 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 electromagneticradiation phenomena (Module 3).

4 Will understand the important concepts involved in special theory of relativity and its intimate connection to the electrodynamics phenomena (Module 4).

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 neara 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 fieldand 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, electromagneticfield 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)

PHY 10704: Quantum Mechanics-I

Credits: 4
Hours : 72 hours

Course Objectives

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, observablesand 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 me-chanics

Course Outcomes

1 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).

2 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).

3 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).

4 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 (Module IV).

Module I - Linear Vector Spaces

de Broglie’s hypothesis: matter waves and experimental confirmation, wave packets; Linear vector spaces: inner product, Hilbert space, Wave Functions; Linear operators: Hermitian operators, Projec-tion 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, Rep- resentation 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 functionsof of L^2 and L_z ; Hydrogen Atom; Scattering: Cross Section,Amplitude and Differential Cross Section, Scattering of Spin-less Particles, The Born Approximation, Validity of the Born Approximation.

Text Books:

1 Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009

2 David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004

Reference Books:

1 J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley,1994

2 R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994

3 Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill,2010

4 V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985

Semester VIII

PHY 10801: Quantum Mechanics-II

Credits: 4
Hours : 72 hours

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 parti-cles.
- Formulate the time independent perturbation theory to find energy eigen values and eigen func-tions 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
- Discuss indistinguishably in multi-particle quantum systems and their wave-functions.

Course Outcomes

1 Students will get a complete understanding of the total and the spin angular momenta of fun-damental particles. They will also understand how angular momenta will add in a combined system. This is crucial to understand spectroscopy (Module I)

2 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 (ModuleII)

3 Perturbative approach to solve time-dependent problems will be understood. Various applica-tions like Fermi's Golden rule, semi-classical theory of radiation will also be introduced (Module III)

4 Student will understand to formulate a relativistic theory of quantum mechanics and also multiparticle quantum mechanics (Module IV)

Module I - Quantum Theory of Angular Momentum

Review of Orbital angular momentum; Total 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 with no rigid walls, 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, Probability density, Solution of free Dirac equation and positrons; 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

Text Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009
2. J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley,1994
3. Walter Greiner, Relativistic Quantum Mechanics Wave Equations, 3rd Edition, Springer, 2000 (Module IV)

Reference Books:

1. R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994
2. David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004
3. Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill,2010
4. V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985 (Module IV)

PHY 10802: Statistical Physics

Credits: 4
Hours : 72

Course Objectives

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 behaviorof a system.

Course Outcomes

Upon completion of this course, a student should be able to -

1 Differentiate between systems in equilibrium and out of equilibrium.

2 Demonstrate an understanding of the terminology, concepts and principles of describing equilib-rium properties of physical systems.

3 For a given ideal system, derive various macroscopic quantities - either using a classical or aquantum setting - using the principles learned.

4 Derive the macroscopic properties of ideal quantum gases.

5 Develop a basic understanding of various aspects of the statistical physics of systems with inter-action between its constituent components.

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 witha 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, en-tropy of mixing and Gibbs paradox, Maxwell velocity distribution, harmonic oscillator, The equipar-tition 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).

PHY 10803: Atomic and Molecular Spectroscopy

Credits: 4
Hours : 72 hours

Course Objectives

Atomic and molecular spectroscopy has played an integral role in providing the necessary information leading to the development of quantum mechanics and to the understanding of the building blocks of matter. 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 application in molecular structure determination and medicine. This course also aims to give the detailed working principle of different laser systems, which has numerous applications in industry, material science, medicine, and telecommunications.

Course Outcomes

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

1. Describe the electronic state of atoms in terms of quantum numbers, the complexity of atomicspectra due to spin-orbit coupling, and the interpretation of term symbols. (Module 1)
2. Explain how atoms absorb and emit light and how this process can be affected by magnetic andelectric fields. (Module 1)
3. Explain the contributions of transitions between rotational, vibrational and electronic states tothe spectra of diatomic molecules. (Module 2)
4. Describe how IR and Raman spectroscopic techniques are used in molecular structure determi-nation (Module 3)
5. Distinguish different spectroscopic techniques (absorption, fluorescence, Raman, NMR, and EPR) (Module 3)
6. Write the rate equations of three-level and four-level laser systems, and to describe the workingprinciple of specific laser systems. (Module 4)

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 Doppler and natural broadening

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 andinstrumentation for microwave spectroscopy. The vibrating diatomic molecule - simple harmonic oscil- lator, 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 instru- mentation of Raman and IR spectroscopy, structure determination by IR and Raman spectroscopy- simple examples, fundamentals of SERS. Nuclear and electron spin - interaction with applied mag- netic 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 source, and the optical resonator, Phenomenon of population inversion, Characteristics of laser light, Three level laser

- Four level laser - rate equations - pumping threshold, Specific laser systems - He-Ne laser -Argon ion laser - CO2 laser - excimer laser - ruby laser - dye laser - Nd:YAG laser - semiconductor diode lasers.

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, McGrawHill Education (2017).

Reference Books:

1. Laser fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
2. Lasers Theory and Applications, 2nd Ed., K. Thayagarajan and A.K Ghatak, Springer (2011).
3. Molecular structure and Spectroscopy (2nd Edition), G. Aruldhas, Prentice Hall of India (2007).
4. Spectroscopy Vol. I, II and III, B.P. Straughan and S.Walker, Chapman and Hall (1976).
5. Introduction to Molecular Spectroscopy, G. M. Barrow, McGraw-Hill Inc.,US (1962).
6. The Physics of Atoms and Quanta (4th ed.), H. Haken and Hans C. Wolf, Springer-Verlag (1994).
7. Laser Physics, Peter W. Milonni and Joseph H. Eberly, Wiley-Blackwell (2010).
8. Optical Electronics, A.K.Gahtak and K. Thayagarajan, Cambridge University press (1989).

PHY 10804: Advanced Electronics

Credits: 4
Hours : 72 hours

Course Objectives

Advanced level knowledge in Electronics is essential to understand the working of computers, telecom- munication systems, sophisticated analytical instruments, and other electronic appliances in our every- day 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 etc. The students should also be able to understand the role of electronics in microprocessor architectures and analog and digital communication.

Course Outcomes

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

1. Explain the working of different combinational and sequential logic circuits and its design usinguniversal-NAND gates. (Module 1)
2. Understand the primary applications of the operational amplifier as an adder, subtractor, dif- ferentiator, integrator, comparator, and waveform generator etc. (Module 2)
3. Design Op-amp circuits to find the solutions of differential equations. (Module 2)
4. Explain the architecture of 8085 Microprocessor, instructions, and its working. (Module 3)
5. Write assembly language program for 8085 Microprocessor (Module 3)
6. Demonstrate the working principle and instrumentation of analog and digital communications.(Module 4)

Module I

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, serialand 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 II

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 equa- tions – general ideas about analog computation and simulation – other applications of Op-amps, filters,comparators, sample and hold circuits, waveform generators.

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

Amplitude Modulation – Double and Single sideband techniques – Frequency modulation and Demod- ulation techniques – Bandwidth requirements – Pulse communication – Pulse width, Pulse position and Pulse code modulation – Digital communication – error detection and correction – frequency and time division multiplexing.

Text Books:

1. John Ryder, Electronic Fundamentals and Applications (5th Edition), Prentice Hall, New Delhi,(1983).
2. Milman and Halkias, Integrated Electronics, Mc. Graw Hill, (1983).
3. Robert G. Irvine, Operational Amplifier – Characteristics and Applications, 2nd Edition, Pren-tice Hall, New Jersey (1987).
4. Gaonkar, Microprocessor Architecture, Programming and Applications, Wiley Eastern Limited,New Delhi (1992).

Reference Books:

1. John Wakerly, Digital Design: Principles and Practices (4th Ed.), Prentice Hall (2005).
2. D. C. Green, Digital Electronics (5th Ed.), Pearson Education Ltd., (2005).
3. Roddy and Coolen, Electronic Communications, Prentice Hall 4th Ed (1995).
4. B. P. Lathi, Modern Digital and Analog Communication Systems 3rd Ed, Oxford Universitypress (1998).

Semester IX

PHY 10901: Nuclear and Particle Physics

Credits: 4
Hours : 72 hours

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

1 Describe the basic properties of the nuclear force. (Module 1)

2 Explain the nucleon-nucleon scattering and its underlying principles. (Module 1)

3 Review the different nuclear models and nuclear reactions. (Module 2)

4 Discuss nuclear fission and its applications. (Module 2)

5 Classify different nuclear radiations and radiation detectors. (Module 3)

6 Explain the properties of the nucleus.

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 quarksand 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 Univer-sity 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).

PHY 10902: Advanced Solid State Physics

Credits: 4
Hours : 72 hours

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

After completing this course the students should be able to:

1. Understand the underlying physics of solid-state materials. (Module 1 to module 5).
2. Understand the historic development of solid-state physics and how they explain specific heatof solids. (Module 1).
3. The details about the vibrations in the atomic chain and the applications of scattering experi-ments in solids. (Module 2)
4. Summarize the details of band theory and the developments of semiconductor physics and band-gap engineering. (Module 3).
5. The magnetic properties of solids, its microscopic details, and mean-field theories are covered.

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 theFree 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 Scat- tering 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- NearlyFree 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) Mag- netic 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 Elementary Solid State Physics: Principles and Applications, Ali Omar, Pearson (1993).
3 Elements of x-ray diffraction (3rd edition), Cullity, B. D. and Stock, Stuart H., Prentice Hall(2001).

Elective Courses

06: 2D Materials

Course Code: 06
Credits: 4
Hours : 72

Course Objective

To introduce the field of 2D materials, different classes and their properties.

Course Outcome

1. To familiarise with low dimensional structures and their properties.
2. To learn about 2D material families (Graphene, 2D transition metal chalcogenides/carbides).
3. To familiarise with properties and applications of 2D materials.
4. To introduce 2D topological materials.

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 - Open- ing 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- appli- cations 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). Prop- erties: 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 mate- rials, 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.

07: Advanced Magnetism and Magnetic Materials

Course Code: 07
Credits: 4
Hours : 72 hours

Course Objectives

1. A postgraduate level course in Advanced Magnetism and Magnetic Materials will help in studenthaving a thorough understanding of magnetism in condensed matter.
2. This course will equip the student with required prerequisites to proceed with a Ph.D. programin condensed matter physics or with a scientific position in magnetic materials industry.

Broad contents of the course

1. Review on fundamental magnetism
2. Diamagnetism and Paramagnetism
3. Ferromagnetism, Antiferromagnetism, and Ferrimagnetism
4. Magnetic anisotropy and Applications

Skills to be learned

1. This course will help in having a thorough understanding of magnetism in condensed matter.
2. A postgraduate level course in Advanced Magnetism and Magnetic Materials will equip the student with required prerequisites to proceed with a Ph.D. program in condensed matter physicsor with a scientific position in a 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. On successful completion of this course, students will be able to:

1. Explain paramagnetism based on both classical and quantum mechanical theory
2. Calculate the diamagnetic susceptibility of a solid.
3. Articulate knowledge of ferromagnetism in 3d transition metals.
4. Demonstrate a working understanding of permanent magnets, magnetic data storage, and mag- netic refrigeration
5. Explain different types of interactions in a magnetic solid and ordered magnetic structures.
6. Understand the origins of magnetic anisotropy and correlate the technical magnetic properties with the underlying microstructure of the material

Module I

Review on basic magnetism: Magnetic poles - Magnetic flux - Circulating currents - Ampere's circuital law - Biot - Savart law- Field from a straight wire - Magnetic dipole - Magnet induction and magneti- zation - Flux density -Susceptibility and permeability - Hysteresis loops - Solution of the Schrodinger equation for a free atom- Extension to many-electron atoms - Normal Zeeman effect - Pauli exclusion principle - R-S coupling -Hund's rules - jj coupling - Anomalous Zeeman effect

Module II

Diamagnetism and Paramagnetism: Diamagnetism: Diamagnetic susceptibility - Diamagnetic sub- stances & applications - Superconductivity-Paramagnetism: Langevin theory of paramagnetism - Curie - Weiss law - Quenching of orbital angular momentum - Pauli Paramagnetism - Paramagnetic oxygen - Applications of paramagnets

Module III

Ferromagnetism, Antiferromagnetism, and Ferrimagnetism: Interactions in ferromagnetic materials: Weiss molecular field theory - Origin of the Weiss molecular field - Collective-electron theory of fer- romagnetism - Ferromagnetic domains - Observing domains - The occurrence of domains - Domain walls - Magnetization and hysteresis Antiferromagnetism: Neutron diffraction - Weiss theory of an- tiferromagnetism - Cause of negative molecular field - Applications Ferrimagnetism: Weiss theory of ferrimagnetism - Ferrites

Module IV

Magnetic anisotropy and Applications: Magnetocrystalline anisotropy - Shape anisotropy - Induced magnetic anisotropy, Applications of Magnetic Materials-Future of magnetic data storage-Permanent Magnets-Magnetocaloric effect (Elementary)

Text Books:

1 Magnetic Materials Fundamentals and Applications - Nicola A. Spaldin, Cambridge UniversityPress, 2003 [Module 1,2,3 and 4]

2 Physics of Magnetism and Magnetic Materials - K.H.J Buschow and F.R De Boer, KluverAcademic Publishers, London, 2003 [Module 4]

3 Nanoscale Magnetic Materials and Applications - Editors: J.Ping Lu, Eric Fullerton, OliverGutfleish, 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.

3 Molecular Quantum Mechanics - P.W. Atkins. Oxford University Press, 1999.

08: Advanced mathematical physics

Course Code: 08
Credits: 4
Hours : 72

Course Objective

To equip the students to use some of the advance topics of mathematical physics.

Course Outcome

At the completion of this course,

1. The students will acquire an in-depth knowledge about ordinary and partial differential equationsand various methods of finding their solutions.
2. Understand the concepts, terminology and principles of analysing groups.
3. Obtain an understanding of representation theory of groups, particularly symmetry groups, SO(n) group and SU(n) group.
4. Learn the terminology, concepts and principles of analysing tensors. Learn tensor algebra.
5. Learn Christoffel symbols and Reimann curvature tensor which are crucial to understand generalrelativity.
6. Understand basics of stochastic differential equations.

Module I

Review of solving first and second order ordinary differential equations. Review of solving first or- der partial differential equations. Sturm - Liouville theory: eigenvector expansions; Hilbert spaces; self-adjoint operators; eigenfunction expansions; existence of eigenvalues and completeness of eigen- functions; 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 Pub-lishing Co. ISBN 0805370021.

Reference Books :

1. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2001)

09: Advanced Raman Spectroscopy

Course Code: 09
Credits: 4
Hours : 72
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 insights in to different Raman process which has applicationsin 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.

Module I

Raman effect, classical theory of Raman effect, quantum mechanical treatment of Raman effect, Surface-Enhanced Raman Spectroscopy (SERS), Principle of SERS, Enhancement mechanism, Electromagnetic enhancement mechanism, Chemical enhancement, Surface selection rules, SERS substrates, metal films, metallic nanoparticles, Applications-biomolecules, in medicine, forensic science, Hyper Raman effect, Classical treatment of Hyper Raman effect, Experimental techniques for hyper Raman effect, Stimulated Raman scattering, inverse Raman scattering, CARS (Coherent antistokes Raman scattering)

Module II

Raman spectrometer, Major Components, Excitation Sources, 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

Module III

Special techniques, High pressure Raman spectroscopy, Some examples of temperature and pressure induced phase transitions and its sample handling techniques. Raman microscopy, applications, Raman spectro-elctrochemistry- Applications, time resolved Raman Spectroscopy- applications, matrix isolation raman spectroscopy- applications, 2D correlation Raman Spectroscopy- applications, Raman Imaging Spectrometry- applications, Industrial Applications, Environmental applications.

Module IV

Analysis of Raman data, Compounds having inorganic functional groups, molecular symmetry, fundamental modes of vibration, Molecular symmetry, Molecules of type XY2, XY3, XY4, Sulphates, Phosphates, Carbonates, Iodates, Tungstates, Bromates etc. Analysis of Raman spectra of carbon rich compounds, carbon nano tubes, graphite, graphine, Analysis of oxide nano structures, 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, Aca-demic press, Elsevier.

10: Advanced solid state physics-II

Course Code: 10
Credits: 4
Hours : 72 hours

Course Objectives

To make the students learn modern developments in the field of condensed matter physics particularlyto those who wish to do research in this area.

Course Outcomes

1. To understand the different perspectives of the carrier absorption and its transport properties.
2. To familiarize with the theoretical tools like density of states etc.
3. To familiarize with the modern ideas like, quantum well and the associated properties.

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

11: Applied Vibrational Spectroscopy

Course Code: 11
Credits: 4
Hours : 72

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.

Learning Outcomes

A student will be expected to know the techniques to measure Raman and IR spectra of the sample organic and inorganic compounds. The student will also get knowledge about the analysis of Raman and Infrared data of the samples.

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 softwaresfor 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.

12: Astrophysics

Course Code: 12
Credits: 4
Hours : 72 hours

Course Objective

To study in detail the elements of Astrophysics, with an aim to develop the taste of research in the field.

Course Outcome

The learner will,

1. Acquire a thorough understanding of the basic concepts like magnitudes, color, H-R diagrametc.
2. Understand the theory of hydrostatic equilibrium in stars.
3. Get a clear idea about the energy production in stars.
4. Get a clear knowledge about the evolution of the main sequence stars.

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 pub-lishing 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)

13: Biophysics

Course Code: 13
Credits: 4
Hours : 72

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

After completion of this course, the students will have good fundamental understanding of biophysics and its allied areas related to including structure determination of proteins.

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 cul- tures(Qualitative treatment)-Sedimentation of cell cultures.

Module III

Nerve impulses-Neurotransmitters and synapses-Passive and active transports in dendrites- Mechan-ical 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 Uni-versity Line, 1999.

14: Complex networks

Course Code: 14
Credits: 4
Hours : 72
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

Upon completion of this course, a student should be able to

1. Demonstrate an understanding of the terminology, concepts and principles of the study of com-plex networks.
2. Identify problems that can be treated using the tools of complex networks.
3. Calculate various properties of a complex network related to its local structure.
4. Calculate various properties of a complex network related to its global structure.
5. Demonstrate an understanding of various models of complex networks and their properties andapplications.

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).

15: Computational Physics

Course Code: 15
Credits: 4
Hours : 72 hours

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.

Course Outcome

Students will develop skills in solving problems in various areas of Physics using appropriate numerical methods and simulation techniques, on a Computer.

Main Prerequisite

Bachelor level understanding of Physics and Mathematics.

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 equa- tion.

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).

16: Crystal Growth

Course Code: 16
Credits: 4
Hours : 72 hours

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

After completion of this course, the students will have good fundamental understanding on crystal growth.

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 - Re- duction 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 Publi-cations, 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 Uni-versity Line, 1999.

17: Elementary astronomy

Course Code: 17
Credits: 4
Hours : 72

Course Objective

This course enable the students learn the salient advancements in the field of Astronomy.

Course Outcome

1. Get knowledge about the celestial sphere and its various properties and uses.
2. Get good knowledge regarding the theories of solar system, planets - their formation and prop-erties.
3. Get a reasonable knowledge about the formation of stars, and objects like white dwarf, blackhole etc.

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 globularclusters. 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)

18: Fundamentals of Photovoltaics

Course Code: 18
Credits: 4
Hours : 72

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

After the successful completion of the course the students will be able to confidently:

1. Explain the working principle of solar cells
2. Understand PV based electricity generation
3. Differentiate the manufacturing and performance differences between different c- Si wafer tech-nologies and between ?c-Si and thin film PV technologies
4. Identify the critical losses and loss mechanisms in c-Si solar cells
5. Calculate the power and energy produced by a solar module
6. Explain the differences and design aspects of off-grid and on-grid PV systems.

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

19: Gravitation and Cosmology

Course Code: 19
Credits: 4
Hours : 72

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

1 Students will learn tensor algebra and using it they will understand the general theory of relativity.

2 Students will apply general theory of relativity to various astrophysical systems like planetary motion, black holes and gravitational waves. They will find that new physics is emerging as a consequence of Einstein's theory compared to Newton's law of gravity.

3 Students will understand models of expanding Universe in connection with the general theory ofrelativity. They will be introduced to concepts of exotic components of matter in the Universe like dark matter and dark energy.

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, cosmo- logical 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 UniversityPress, 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)

20: Laser and Nonlinear Optics

Course Code: 20
Credits: 4
Hours : 72

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

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

1. Analyse the propagation of Gaussian beams.
2. Apply the principles of phase contrast imaging.
3. Illustrate pulse shortening mechanisms and chirped pulse amplification.
4. Elaborate high power laser interaction with material.

Module I

Review of Radiation Laws (Stefan Boltzmann, Wien Displacement, Planks) and basics of lasers (Pop- ulation 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)

21: Light Sources and Detectors

Course Code: 21
Credits: 4
Hours : 72

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

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

1. Explain the difference between natural and artificial sources of light.
2. Explain the basic characteristics and working principle of various photon sources and detectorsin ultraviolet-visible-infrared regions of the electromagnetic spectrum.
3. Demonstrate the safety procedures to be taken while setting up experiments with advancedoptical sources and detectors.

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), SupercontinuumSources.

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 AppliedOptics), Wiley, New York (1984).

References

1 Kingston, Robert H., Detection of Optical and Infrared Radiation, (Springer Series in OpticalSciences, 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)

22: Measurements and Optical Instrumentation

Course Code: 22
Credits: 4
Hours : 72 hours

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 detectorsand spectroscopic instruments.

Course Outcomes

A student will be expected to be able to know the techniques to reduce errors in measurements and reduction of noises in experimental data. The student will also get knowledge about different types of optical detectors and the design concept of optical spectrometer.

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, spectropho- tometers, calorimeters Spectrometer Design.

Text Books:

1. Measurement, Instrumentation and experiment design in Physics and Engineering Michael Sayerand 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).

23: Modern Optics

Course Code: 23
Credits: 4
Hours : 72

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

At the end of the course, the student will be able to:

1 Illustrate and apply principles of optical systems.

2 Apply concepts for the design of high and anti-reflection coatings, interference filters etc.

3 Employ the theory of interference and diffraction for the development of devices like zone plates,holographic recording and re-construction.

4 Illustrate pulse shortening mechanisms and pulse amplification in modern lasers.

5 Explain linear to nonlinear transformation in laser material interactions.

6 Embrace lifelong learning and scientific research.

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 gener- ation – 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).

24: Molecular physics and laser spectroscopy

Course Code: 24
Credits: 4
Hours : 72

Course Objective

To impart the modern ideas and applications of Molecular Physics and spectroscopy.

Course Outcome

Students who completed this course will,

1. Have basic knowledge of the chemical bonding in molecules and also adequate knowledge inValence theory
2. Posses the knowledge about the structure properties of polytropic molecules including water molecule.
3. Know the spectra of different molecules, which will enable to identify the molecule through aspectroscopic study.

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 rota- tional 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. Dun-ham representation of re-vibrational transitions. (basic ideas only)
CW dye laser spectrometers - basic ideas of intermodulated fluorescence spectroscopy – Microwavefrequency - 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

25: Nondestructive measurement techniques and applications

Course Code: 25
Credits: 4
Hours : 72

Course Objective

To make the learner understand the modern trends in measurement techniques.

Course Outcome

To get a thorough knowledge in,

1. Magnetic techniques used for measurements.
2. Radiography and alleid techniques.
3. Ultrasound testing method and related phenomena.

Module I

Magnetism-Basic Definitions- Principle of MPT - Magnetizing Techniques -Magnetization 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 mea-surements.

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 ultra-sonic beam - Attenuation - Inspection methods - Normal incident pulse-echo inspection - Normal inci- dent 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 char- acterization 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 application of holography- Holographic interferometry-Real time holographic interferometry-Double-Exposure holographic interferometry- Sandwitch holograms- Holographic interferometry in an industrial environment- Holographic strain analysis Raman effect (Qualitative only), Raman spec- troscopy as nondestructive tool. Instrumentation.

Text books

1 Practical Nondestructive Testing, Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Pub-lishing House New Delhi

2 Optical Holography-Principles techniques and applications, P.Hariharan, Cambridge Studies inModern Optics

Reference Books :

1 Electrical and Magnetic Methods of Non -Destructive Testing, Jack Blitz,Champan & Hall,2-6Boundary Row,London SE1 8HN

2 Optical Electronics Ajoy Ghatak and K.Thygarajan,Cambridge University Press India Pvt.Ltd

3 Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi

26: Non-equilibrium statistical physics

Course Code: 26
Credits: 4
Hours : 72

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

At the end of the course the learners will be able to:

1 Get a grasp on various theoretical methods useful in understanding non-equilibrium phenomena

2 Solve problems in stochastic processes and to predict the distributions of random variables.

3 To differentiate non-equilibrium systems from equilibrium systems wherever applicable.

4 To apply large deviation theory in physical systems.

5 Understand the technical terminology, and to follow the scientific literature of past and recentadvances in the field.

Module I

Introduction to stochastic processes: basics of probability theory, Random numbers, Probability distri- butions, Moments, cumulants, generating functions Central limit theorem, Levy stable distributions.

Module II

Brownian motion, first passage properties, Markov processes, Master equation, Detailed balance con- dition, 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 the- ory, 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 PersonalLibrary) North Holland; 3rd edition.

2 V Balakrishnan, Elements of Nonequilibrium statistical mechanics, Ane books, Delhi & CRCPress (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 (OxfordGraduate Texts)

3 The mechanics and statistics of Active matter, Sriram Ramaswamy, Annual Review of CondensedMatter Physics 323-345 (2010).

27: Non-linear dynamics and chaos

Course Code: 27
Credits: 4
Hours : 72 hours

Course Objectives

To make the students understand the field of non-linear dynamics.

Course Outcomes

1 Understanding the basic of non-linearity in physical systems.

2 Understanding the discrete dynamical systems, logistic map and associated things.

3 To familiarise the concepts like Lyapunov exponents and its application in detecting chaos insystems.

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)

28: Non-linear optics

Course Code: 28
Credits: 4
Hours : 72

Course Objective

Aquire the modern ideas on Non-linear optics.

Course Outcomes

1. Get a thorough knowledge of polarizability and wave propagation in dielectric material.
2. Get a clear knowledge of second harmonic generation, four wave mixing, phase-conjugation, etc.
3. Get good hand on the ideas of resonating oscillators.

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. Blochequations – 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 guideproperty 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

29: Phase transition and critical phenomena

Course Code: 29
Credits: 4
Hours : 72

Course Objectives

To understand how to develop the physics of a system in equilibrium with many interacting components.
Understand the physics of phase transitions and related critical phenomena.

Course Outcomes

1. Get an in-depth understanding of equilibrium statistical mechanics.
2. Acquire the ability to develop a quantitative theory of a system with many interacting degreesof freedom using exact and approximate methods.

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).

30: Physics of Nanomaterials

Course Code: 30
Credits: 4
Hours : 72

Course Objectives

The course aims to develop an understanding of nanostructured materials and its various synthesis methods and characterization techniques. After completing the course, the students will be able to:

- Understand the fundamental differences between nanostructured materials and bulk materials.
- Classify 0D,1D,2D, and 3D materials and its optical, electrical, and magnetic properties.
- Differentiate Bottom-up and Top-down methods used for nanomaterials synthesis.
- Assess different characterization tools used for understanding the size and distribution of nano-materials.

Course Outcomes

The student can explain

1. The primary difference between bulk material and nanomaterial
2. Classify the nanomaterials based on the dimension.
3. Understand weak and strong excitonic confinement.
4. Explain the blue shift in metals and semiconductors
5. Explain different methods for nanomaterial synthesis
6. Explain diverse characterization tools used in nanotechnology
7. Able to calculate particle size using Debye-Scherrer formula
8. Differentiate the purpose of using the characterization tools like SEM, TEM, XRD, and AFM.

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 magne- toresistance (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, solvother- mal 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 anddesign, an introduction for engineers and architects, Elsevier (2009).

2 S.V. Gaponenko, Optical properties of semiconducting nanocrystals, Cambridge University Press(1997).

3 Transmission Electron Microscopy: A textbook for materials science, David B. Williams, C.Barry Carter, second edition, Springer.

4 Elements of X-Ray diffraction, B. D. Cullity, S. R. Stock, 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-sciencepublication (1993)

3 A I Gusev and A A Remphal, Nanocrystalline materials, Cambridge International Science Pub-lishing

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).

31: Principles of Biomedical instruments

Course Code: 31
Credits: 4
Hours : 72

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

After completion of this course, the students will have good understanding, on biomedical instruments

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

Xrays: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 Radiog- raphy systems – Exposure switching and control of exposure time – Types of timer circuits, Filamentcircuit 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 de- tection, 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. Ul- trasound 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 :

X.1 Fundamental Physics of radiology,W.J. Meredith & J.B. Massey, Varghese Publishing House,Bombay, 1992.

X.2 The Physics of Diagnostic Ultrasound, Peter Fish, John Wiley & Sons, England, 1990. 4.

X.3 Ultrasound Physics & Instrumentation,D.L. Hykes, W.R. Hedrick & D.E. Starchman, ChurchillLivingstone, 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,1989India 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.

32: Quantum field theory

Course Code: 32
Credits: 4
Hours : 72

Course Objectives

To introduce the basic concepts and methods of classical and quantum field theory.

Course Outcomes

1. To understand the basics of classical field theory concepts and methods of calculation
2. To understand about the scalar field and Feymann propagator and it's usage.
3. To familiarize with the idea of quantization of the filed and allied facts.

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--canon-ical 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-Lagrangiandensity.

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(noproof), 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 ofgauge 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)

33: Quantum Computation and Information

Course Code: 33
Credits: 4
Hours : 72

Prerequisites

Knowledge of basic quantum mechanics and Mathematical Physics.

Course Objectives

Course Outcomes

Students will get an overview of the emerging field of quantum computation and the techniquesinvolved in that.

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)

34: Quantum optics

Course Code: 34
Credits: 4
Hours : 72

Course Objective

To teach the students about the basics and sufficient advanced ideas of Quantum Optics.

Course Outcome

1. The students must acquire sufficient knowledge regarding the radiation-matter interaction
2. A thorough understanding of the black body radiation and laser theory
3. Get a clear idea about the modern concepts like, Doppler broadening, multimode field quanti-zation, etc.

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 suscepti-bilities.

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 Gaus-sian 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 – collapseand 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

35: Solar Photovoltaic Technology

Course Code: 35
Credits: 4
Hours : 72

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 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

After the successful completion of the course the students will be able to confidently:

1. Understand PV based electricity generation
2. Differentiate the manufacturing and performance differences between different c- Si wafer tech-nologies and between ?c-Si and thin film PV technologies
3. Calculate the power and energy produced by a solar module
4. Explain the differences and design aspects of off-grid and on-grid PV systems.
5. Basic knowledge to use PVSyst.
6. Explain various current and futuristic applications of PV.

Module I

Introduction: Energy scenario - Fossil fuel and Climate change - Renewable Energy sources - Integrat- ing 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 - silicon feed stock - production of silicon wafers - Manufacturing process of c-Si solar cells - high efficiency approaches - PERL and PERC cells - interdigitated back contacts - TOPCon - heterojunction solar cells - lab to industry requirements
Second generation: Thin film technologies: Merits and demerits of thin film technologies - Transparent conducting oxides - GaAs, amorphous-Si, CdTe and CIGS solar cells Third generation/emerging PV technologies: Organic PV - organic-inorganic hybrid solar cells - Quantum-dot - Hot-carrier - Up conversion and down conversion

Module III

Solar cell to modules: silicon feed stock - production of silicon wafers - Manufacturing process of c-Si solar cells – 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: introduction to PVSyst software, Lighting, agriculture, refrigeration, telecommunications, space, BIPV, fencing, water purifi- cation, navigation, solar cars, defense, etc.

Text Books:

1. S.R. Wenham, M. Green, M.E. Watt, R. Corkish, A. Sproul, Applied Photovoltaics ? 2ndEdition (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 engineeringof 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 UniversityPres (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

36: Sophisticate Material Characterization Techniques

Course Code: 36
Credits: 4
Hours : 72

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

After completion of this course, the students will have good fundamental understanding, on different types of sophisticated material characterisation techniques.

Module I

xray 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 diffractome- ter – Electron diffraction-Neutron diffraction- Reflection high energy electron diffraction (RHEED),XPS-principle-Instrumentation and applications-X-ray topography(XRT)- Rutherford Back Scatter- ing 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 Mi- croscope (TEM) - Scanning transmission electron microscopy (STEM)- Atomic Force Microscope- Ele- mental composition analysis-EDX-EELS- Auger electron spectroscopy (AES)- Optical measurements- UV-visible spectroscopy- Determination of band gap of semiconductors- Atomic emission spectrome- try.

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 Inter- ferometer Quantitative analysis- Sample handling. - Luminescence –Photoluminescence(PL) spec- troscopy–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 calorime-try - Thermogravimetry - Instrumentation - Methodology of Differential Scanning Calorimetry andThermo Gravimetric Analysis - Conductance method – Electrical conductivity-Measurement of electri- cal conductance - Measurement of dielectric constant- Hall Mobility – Magnetic measurements-SQUIDmagnetometer- 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 publish-ers.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 ofSQUIDs and SQUID Systems- Wiley-VCH.
10. Banwell and E M McCash, Fundamentals of Molecular Spectroscopy; McGraw-Hill Education(India) Pvt Limited, 2001.

37: Thin film physics

Course Code: 37
Credits: 4
Hours : 72

Course Objective

To impart the modern ideas of thin film technologies used in various solid state physics and day today applications.

Course Outcome

1. To familiarise with the different thin film deposition methods.
2. To understand the nuclear theories of thin film formation.
3. To familiarise with the measurements techniques of the properties of thin films.
4. Awareness and knowledge of various application of thin films in semiconductor devices and inday today life.

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 - Evapora-tion 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 depo-sition: 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 – Atom-istic 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 internationalEdition, 1995.

3 Various web resources and research papers

38: Ultrashort Pulse Lasers and Applications

Course Code: 38
Credits: 4
Hours : 72

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

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

1. Illustrate process of generation, amplification, and measurement of ultrashort lasers.
2. Analyse high power relativistic and non-relativistic laser interaction with gaseous and condensedmedia.
3. Evaluate Research Opportunities and technology of intense field interaction physics.
4. Develop lifelong learning skills through research.

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.

DEPARTMENT OF STATISTICS

Scheme of Examinations and Syllabus for the Five-Year Integrated M.Sc. Statistics Degree Program

(From 2021 admission onwards)

Cochin University of Science and Technology

Cochin - 682 022

Approved by the BOS in Physical and Mathematical Sciences 17-07-2021

Website: http://statistics.cusat.ac.in

SEMESTER V

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
MAM 10501	Analysis I	C	4	50	50	100
MAM 10502	Linear Algebra and Geometry in R^n	C	4	50	50	100
MAM 10503	Algebra: Groups and Rings	C	4	50	50	100
MAM 10504	Introduction on to Complex Analysis	C	4	50	50	100
STA10501	Statistics and Probability II	C	4	50	50	100
	Total		20	250	250	500

SEMESTER VI

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
MAM 10601	Analysis II	C	4	50	50	100
MAM 10602	Ordinary and Partial Differential Equations	C	4	50	50	100
MAM 10603	Complex Analysis and Number Theory	C	4	50	50	100

SEMESTER VII

STA -10701		Mathematical Methods for Statistics	C	4	50	50	100
STA-10702		Probability Theory I	C	4	50	50	100
STA-10703		Probability Distributions	C	4	50	50	100
STA-10704		Sampling Theory &	C	4	50	50	100
		Methods					
	Elective - I (Choose any one)						
STA-10705		Elective – I: Data Analytics using R	E	3	50	50	100
STA-10706		Statistical Computing	E	3	50	50	100

		Total		19	250	250	500

SEMESTER – VIII

Course Code	Title of Paper	Core/Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
STA-10801	Statistical Inference I	C	4	50	50	100
STA-10802	Probability Theory II	C	4	50	50	100
STA-10803	Stochastic Processes	C	4	50	50	100
STA-10804	Practical - I and Viva Voce	C	2	100	-	100
Elective – II (Choose any one)						
STA-10805	Statistics for National Development	E	3	50	50	100
STA-10806	Reliability Modelling and Analysis.	E	3	50	50	100
Elective - III						
STA-10807	** A suitable Online course	E	2	50	50	100
	Total		**19**	**350**	**250**	**600**

SEMESTER – IX

Course Code	Title of Paper	Core/Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
STA-10901	Statistical Inference II	C	4	50	50	100
STA-10902	Multivariate Analysis	C	4	50	50	100

STA-10903	Applied Regression Analysis	C	4	50	50	100
STA-10904	Practical - II using SPSS/ MATLAB	C	2	50 (practical) + 50 (viva)	-	100
Elective – IV (Choose any one of the following)						
STA-10905	Topics in Stochastic Finance	E	3	50	50	100
STA-10906	Operations Research-II	E	3	50	50	100
Elective V Either an inter-departmental course or an online course**						
STA-10907	STA 1[[0907 Elected course	E	3	50	50	100
	Total		**20**	**350**	**250**	**600**

SEMESTER - X

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
STA-11001	Design and Analysis of Experiments	C	4	50	50	100
STA-11002	Practical – III using SAS/R , and Viva Voce	C	4	50	50	100
STA-11003	Project***	C	5	100	--	100
Electives - VI, VII, VIII. (Choose any three)						
STA-11004	Statistical Quality	E	3	50	50	100
	Assurance					
STA-11005	Time Series Analysis	E	3	50	50	100
STA-11006	Lifetime data analysis.	E	3	50	50	100
STA-11007	Applied	E	3	50	50	100

	Multivariate Statistical Analysis.					
STA-11008	Statistical Forecasting	E	3	50	50	100
STA-11009	Inference for Stochastic Processes	E	3	50	50	100
STA-11010	Online course**	E	3	50	50	100
	Total		**22**	**350**	**250**	**600**

* The Viva Voce examination in STA-11002 is to be conducted externally with at least one external examiner (50 marks). The project evaluation is based on a dissertation of STA-11003 shall be done in semester X internally with 100 marks.
** An online course from SWAYAM/NPTEL will be opted by students in consultation with the DC. *** Project allotment and progress assessment will be done during the IX semester. Final evaluation will be done during the X semester.

Method of Evaluation : 50% weightage for Continuous evaluation and 50% for End semester examination.

Continuous evaluation based on internal tests, assignments, seminars and class attendance as per regulations of the University from time to time.

DETAILED SYLLABUS

SEMESTER V

STA10501: Statistics and Probability II

This course is meant for students opting Mathematics/Statistics for their M.Sc.

Hours per week – 4+1, Number of credits -4

Objective: This course introduces Probability and Statistics in a more rigorous manner.

Outcome: After completing the course, students are expected to equipped with useful tools and techniques in Probability and Statistics.

Syllabus

Module I: Review of classical and frequency approaches to probability. Fields, sigma fields and Random variables, Axioms of probability, distribution function and properties. Functions of random variables. Expectations and moments, Moment generating functions.

Module II: Properties of Standard discrete and continuous distributions: Uniform, Normal, exponential, gamma, Weibull, Bernoulli, Binomial, geometric, Poisson, negative binomial, hypergeometric (mean, variance, moment generating functions, inter-relationship among distributions). **ModuleIII**:Modes of convergence: (only definitions, inter-relationships and examples).

Weak law and strong laws of large numbers (definitions, statements of standard limit theorems and examples for iid case only). Central limit theorem for independent and identically distributed random variables (statements of the theorems, examples and applications).

Module IV: Sampling distributions: Chi-square, t-, F and their properties such as genesis, moments and inter-relationships. Methods of estimation (moments, MLE), properties of good estimators, Statement of important theorems (eg: Rao Blackwell, Cramer Rao, ..),

Module V: Fundamentals of testing of hypothesis, Neyman-Pearson lemma with examples. Basic concepts of nonparametric tests. Sign test, signed rank test, Kolmogorov Smirnov test, Mann Whitney test.

Text Book:

Rohatgi, V. K. and Saleh, A.K.Md. Ehsanes (2001). An Introduction to Probability and Statistics, 2ndEdn. John Wiley and Sons.

Reference Books

1. Gupta S. C. and Kapoor V. K.(2002). Fundamentals of Mathematical Statistics, 11thedition, Sultan Chand and Sons.

2. Hogg R. V., Mckean J. W., and Craig A. T.(2014) Introduction to Mathematical Statistics,6th edition, Pearson Education Inc.

SEMESTER VI

STA10601: Design of Experiments and Sample Surveys

This course is meant for students opted for M.ScStatisitcs.

Hours per week : 4+1, Number of credits = 4

Objective: This course introduces basic tools in Sample survey and design of experiments.

Outcome: After completing the course, students are expected to know fundamental aspects of sample survey and analysis of variance.

Syllabus

Module I: Analysis of variance - introduction, One-way classification- fixed and random effect models.

Module II: Two-way classification (one observation per cell) – fixed and random effect models, Tukey's test.

Module III: Experimental design – basic principles, completely randomised design (CRD), randomized block design (RBD), Efficiency of RBD relative to CRD, Latin square design – concepts and applications. **Module IV**: The principle steps in a sample survey, Sampling and non-sampling errors, Sample v/s complete enumeration, Types of sampling, Simple random sampling (SRS) - method of selection of SRS, Estimation of population mean and total, Sample size for a given margin of error.

Module V: Stratified random sampling - method of allocation and estimation of population mean, systematic sampling - method of allocation and estimation of population mean, Cluster and multistage sampling.

Text Books:

1. S.C.Gupta and V.K.Kapoor (2014) Fundamentals of Applied Statistics, Fourththoroughly Revised Edition, Sultan Chand & Sons, New Delhi.

2. P.Mukhopadhyay (2016) Applied Statistics, Second edition (thoroughly revised),Books and Allied (P) Ltd., Kolkata.

Reference Books:

1. W.Cochran (2007) Sampling Techniques, Third Edition, Wiley India Private Ltd,New Delhi.

2. P.Mukhopadhyay (2016) Theory and Methods of Survey Sampling, Second Edition,PHI Learning Private Ltd, New Delhi.

3. D.C.Montgomery (2013) Design and Analysis of Experiments, Eighth Edition, WileyIndia Private Ltd, New Delhi.

4. M.R.Spiegel, J.J.Schiller, R.A.Srinivasan and D.Goswami (2016) Probability and Statistics, Third Edition, Schaum's Outlines, McGraw Hill Education (India) Private Ltd, New Delhi.

STA10602: Applied Statistics

This course is meant for students opted for M.Sc. Statistics

Hours per week : 4+1, Number of credits = 4

Objective: This course introduces some of the statistical tools for data analysis.

Outcome: After completing the course, the students are expected to take decision on choosing a **suitable statistical tool for the given data set.**

Syllabus

Module I:Index Numbers - Introduction, construction of index numbers, criteria of a good index number, classification of index numbers, base shifting, splicing and deflating of index numbers, index of industrial production, index of agricultural production, uses and limitations of index numbers.

Module II: Regression Analysis – Simple and multiple regression, Basics of fitting and residual analysis, assumptions (such as, independent normal errors with mean zero and constant variance, exogeneity, linear independence of predictors etc.) and their violations **Module III**: Time Series Analysis– Time series, components of time series, determination of trend, seasonal factors using parametric methods, forecasting, HoltWinter method.

Module IV: Multivariate Data Analysis – Multivariate data, plotting multivariate data, matrix scatter plot, contour plot, tours, shadow matrix (for missing values), Andrew's curves, parallel coordinate plots, mean, variance-covariance matrix, median, data depth, **Module V**:Data Mining – Concept of database, extraction of the data, Data warehousing, concept of ROC, specificity, sensitivity, accuracy of an algorithm method. Introduction to pattern discovery, Introduction to clustering

Text Books:

1. S.C.Gupta and V.K.Kapoor (2014) Fundamentals of Applied Statistics, Fourththoroughly revised edition, Sultan Chand & Sons, New Delhi.
2. P.Mukhopadhyay (2016) Applied Statistics, Second Edition (thoroughly revised),Books and Allied (P) Ltd., Kolkata.
3 S.C.Gupta and V.K.Kapoor (2010) Fundamentals of Mathematical Statistics,Eleventh thoroughly revised edition, Sultan Chand & Sons, New Delhi.
4. H¨ardle, W. and Simar, L. (2003). Applied Multivariate Statistical Analysis
5. Han, J., Kamber, M., & Pei, J. (2011). Data mining: Concepts and techniques (3rded.). Waltham: Morgan Kaufmann.

Reference Books:

1. S.P.Gupta (1999) Statistical Methods, Sultan Chand & Sons, New Delhi.
2. D.C.Montgomery, E.A.Peck and G.G.Vining (2006) Introduction to linearregression analysis, Third edition, Wiley India Private Ltd, New Delhi.
3. M.R.Spiegel, J.J.Schiller, R.A.Srinivasan and D.Goswami (2016) Probability and Statistics, Third Edition, Schaum's Outlines, McGraw Hill Education (India) Private Ltd, New Delhi.

SEMESTER VII

STA 10701: MATHEMATICAL METHODS FOR STATISTICS

Course Outcome After the completion of the course the student will be able to	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.	Analysis
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

Module-I

Riemann-Stieltjes Integral:- definition, linear properties, integration by parts, change of variable in a Riemann-Stieltjes integral, reduction to a Riemann integral, step functions as integrators, reduction of a Riemann-Stieltjes integral to a finite sum, Eulers summation formula, monotonically increasing integrators, Riemann's condition, comparison theorems, integrators of bounded variation, sufficient conditions for existence of Riemann-Stieltjes integrals, Mean value theorems of Riemann-Stieltjes integrals, integral as a function of the interval, second mean value theorem for Riemann-Stieltjes integrals.

Module-II

Sequences of functions:- Pointwise convergence of sequence of functions, Uniform convergence and continuity, Cauchy condition for uniform convergence, Uniform convergence of infinite series of functions, Uniform convergence and Riemann-Stieltjes Integration, Uniform convergence and differentiation, Multivariable Calculus:- limit and continuity of multivariable functions, Derivatives of a multivariable function - 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 Lagrnge multipliers

Module-III

Matrices:- Rank of a matrix, elementary transformations of a matrix, reduction to normal form, elementary matrices, elementary transformations and elementary matrices, employment of only row (column) transformations, rank of a product, a convenient method for computing the Inverse of a nonsingular matrix, Generalized Inverse Matrices:- Definition and existence, an algorithm, Solving linear equations - consistent equations, obtaining solutions, properties of solutions, Penrose inverse, Symmetric matrices - properties of generalized inverse.

Module-IV

Quadratic forms:- definition, Quadratic forms in the real field:- reduction in the real field, canonical forms, classification of quadratic forms and its characteristic properties, necessary and sufficient conditions for a definite form, gram matrices, Characteristic roots and characteristic vectors of a matrix:determination of characteristic roots and vectors, characteristic sup-spaces of a matrix, nature of characteristic roots of some special types of matrices, algebraic and geometric multiplicity of a characteristic roots, Cayley-Hamilton theorem, Orthogonal and unitary reductions of quadratic forms:orthogonal reduction of real symmetric matrices, unitary reduction of Hermitian matrices, simultaneous reduction of a pair of quadratic forms, Spectral decomposition of a matrix.

Text Books:

1. Searle, S. R. and Khuri, A. I. (2017). Matrix Algebra Useful for Statistics. Wiley Series in Probability and Statistics, Second Edition.

2. Khuri, A.T. (1993). Advanced Calculus with Applications in Statistics, John Wiley & Sons, Inc., USA, Chapters - 3 and 7

3. Apostol, T.M. (1996). Mathematical Analysis, NarosaPublshing House, New Delhi, Second Edition, Chapters - 6, 7, 9.

4. Shanti Narayan (1991). A text of book of matrices, S. Chand & Company, New Delhi, Chapters - 3, 6, 7, 10, 11.

5. Searle, S.R. (1971). Linear models, John Wiley & Sons, Inc., Chapter - 1.

Reference Books:

1. Gupta, S.L. and Gupta, N.R. (2003) Principles of Real Analysis, Second edition, Pearson Education (Singapore) Pte. Ltd.

2. Widder, D.A. (1996) Advanced Calculus, Second Edition, Prentice Hall, Inc., New Delhi.

3. Nanda, S. and Saxena, V.P. (2000) Real Analysis, Allied Publishers Ltd.

4. Graybill, F.A. (1969) Introduction to matrices with applications in statistics, Wadsworth Publishing Company, USA.

5. Rao, C.R. (2002) Linear statistical inference and its applications, Second edition, Chapter 1b, 1c.

STA10702: PROBABILITY THEORY – I

Course Outcome After the completion of the course the student will be able to	Cognitive level
1. Identify sigma fields and Compute limits of a sequence of random variables.	Apply
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

Module-I

Random variables: Algebra of sets, Fields, Sigma fields, Inverse function, Measurable functions, Random variables, Induced sigma fields, Limits of random variables.

Module-II

Probability: General measure space, Lebesgue measure, Lebesgue-Stieltjes measure, Counting measure and their simple properties, Discrete probability space, General probability space as normed measure space, Induced probability space, Extension of probability measures. Distribution function of a random variable, Decomposition of distribution functions, Distribution function of random vectors.

Module-III

Integration with respect to measure (Introduction only), Expectation and moments: Definition and properties, Moment generating functions, Moment inequalities: C_r-, Holder, Jenson and basic inequalities, Product spaces and Fubini's theorem (idea and statement only), Independence: Definitions, Multiplication properties, Zero-one laws.

Module-IV

Convergence: Modes of convergence, Convergence in probability, in distribution, in rth mean, almost sure convergence and their inter-relationships, Convergence theorem for expectation such as Monotone convergence theorem, Fatou's lemma, Dominated convergence theorem (some remarks on the corresponding theorems for general integrals with respect to measure).

Text Books:

1. Billingsley, P. (1986) Probability and Measure, Second Edition, John Wiley.
2. Bhat, B.R. (2011) Modern Probability Theory, Second edition, Wiley Eastern, Chapters 1, 2, 3, 4, 5, 6, 9.

Reference Books:

1. Feller, W. (1966) An Introduction to Probability Theory and Its Applications, Volume II, Wiley Eastern.
2. Rao, C.R. (1973) Linear Statistical Inference and Its Applications, Wiley.
3. Rohatgi, V.K. and A.K.E. Salah (2001) Introduction to Probability and Statistics, John Wiley and Sons.
4. Basu, A.K. (1999) Measure Theory and Probability, Prentice-Hall.

STA10703: PROBABILITY DISTRIBUTIONS

Course Outcome **After the completion of the course the student will be able to**	**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

Module-I

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 and their properties as special cases of the results from modified power series family, hypergeometric distribution and its properties.

Module-II

Continuous distribution: Pearson family – identifications of the different types, Beta, Gamma, Pareto and Normal Special cases of the Pearson family and their properties. Exponential family of distributions, Compound, truncated and mixture distributions.

Module-III

Sampling distributions: Sampling distributions of the mean and variance from normal population, independence of mean and variance, Chi-square, students and distribution and their non-central forms. Order statistics and their distributions, Conditional distribution of order statistics, distribution of sample range.

Module-IV

Bivariate distributions: Multinominal, bivariate normal, bivariate exponential distribution of Gumbel, Marshall and Olkin and Block and Basu, Dirichlet distribution.

Text Books:

1. Rohatgi V.K (1976) An introduction to Probability Theory and Mathematical Statistics, Wiley Eastern
2. Arnold B.C, Balakrishnan N and Nagaraja H.N (1992). A first course in order statistics
3. Galambos J, and Kotz's (1978): Characterization of Probability distributions, Springer -Verlag.
4. Ord J.K. (1972) Families of frequency distributions Griffin

Reference Books:

1. Johnson N.L, Kotz S and Kemp A.W (1992) Univariate discrete distributions, John Wiley.
2. Johnson N.L, Kotz S and Balakrishnan N (1991) Continuous univariate distributions I & II, John Wiley.
3. Johnson N.L, Kotz S and Balakrishnan N (1995) Multivariate Distribution, John Wiley.

STA10704: SAMPLING THEORY AND METHODS

Course Outcome **After the completion of the course the student will be able to**	**Cognitive level**
1.Apply various sampling procedures like SRS, Stratified, systematic, Cluster etc., and estimate the population parametres for attributes and variables	Apply
2.Estimate population ratio, population mean and population total using ratio, difference and regression estimators	Apply
3.Explain Midzuno-Sen- Lahiri, Murthy's, DesRaj's sampling strategies under varying probability without replacement sampling	Evaluate/Apply
4.Understand various types of errors in surveys, and procedures to rectify them	Apply
5.Understand quota, network and adaptive samplings; and evaluate estimator under adaptive sampling	Apply

Module-1

Basic concepts:- Population, sample, sampling design, interpenetrating subsampling; Simple Random Sampling (SRS):- SRS with replacement, SRS without replacement, confidence interval, estimation of population proportion, determination of sample size, comparison between SRSWR and SRSWOR; Stratified Random Sampling:- estimation of population mean and total, optimum allocation, other types of allocation, comparison with SRS.

Module-II

Estimation of gain due to stratification over SRS, construction of strata, number of strata, Ratio estimator:Bias and mean square error, estimation of variance, confidence interval, comparison with mean per unit estimator, optimum property of ratio estimator, unbiased ratio type estimator, ratio estimator in stratified random sampling; 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.

Module-III

Systematic sampling:- estimation of population mean and variance, comparison of systematic sampling with SRS and stratified random sampling, circular systematic sampling; Cluster sampling:- estimation of population mean, estimation of efficiency by a cluster sample, variance function, determination of optimum cluster size, clusters of varying sizes; Probability proportional to size with replacement sampling:estimation of population mean and total, selection of a ppswr sample; Varying probability without replacement sampling I:- properties of a sampling design, Horvitz-Thomson estimator.

Module-IV

Varying probability without replacement sampling II:-Midzuno-Sen-Lahiri sampling strategy, Desraj, Murthy's; Mutistage sampling:- estimation population total with SRS sampling at both stages, multiphase sampling (outline only); Errors in surveys:- effect of unit nonresponse in the estimate, procedures for unit nonresponse; quota sampling, network sampling; Adaptive sampling:- introduction and estimators under adaptive sampling

Text Books:

1 Mukhopadhay, P (2009) Theory and methods of survey sampling, Second edition, PHI Learning Pvt Ltd., New Delhi, Relevant sections of Chapters 1-16.

2 Sampath, S. (2001) Sampling theory and methods, Alpha Science International Ltd., India, Chapter 10.

Reference Books:

1 Cochran, W.G. (1999) Sampling Techniques, Third edition, John Wiley & Sons.

2 Des Raj (1976) Sampling Theory, McGraw Hill.

3 Murthy, M.N. (1977) Sampling Theory and Methods, Statistical Publishing Society, Calcutta.

4 Singh, D. and Chaudhary, F.S. (1986) Theory and Analysis of Sample Survey Designs, Wiley Eastern.

STA10705:ELECTIVE - I

SEMESTER VIII

STA10801: STATISTICAL INFERENCE – I

Course Outcome After the completion of the course the student will be able to	Cognitive level
1. Summarize the desirable properties of estimator of a parameter or parameters of any given distribution.	Evaluate
2. Relate complete sufficient statistic, Rao-Blackwell theorem and Lehmann-Scheffe theorem.	Analyz
3. Relate Cramer-Rao, Chapmann-Robbin's and Bhattacharya bounds in connection with lower bound for the variance of an unbiased estimator.	Analyze
4.Compute estimator of parameter or parameters of any given using distribution method of moments, method of maximum likelihood and method of minimum variance.	Apply
5.Judge MLE of parameter or parameters of any given distribution possess its invariance and large sample properties	Analyze
6.Compare classical inference and Bayesian inference.	
7. Evaluate Bayes and minimax estimator of parameter or parameters of any given distribution under given prior density and loss function.	Evaluate
8. Illustrate Metropolis-Hasting algorithm, Gibbs sampler and MCMC method.	Analyze

Module-I

Point estimation: Sufficiency and minimal sufficiency, Exponential family of distributions, Pitman family, Factorization criterion, Likelihood equivalence, Unbiased estimation, Completeness, Ancillary statistics and Basu's Theorem, UMVUE estimators and their characterizations, Rao-Blackwell Theorem, Lehmann-Scheffe Theorem, UMVUE estimation of parametric functions from standard distributions.

Module-II

Fisher information measure and its properties, Fisher information matrix, Lower bound to the variance of an unbiased estimates, Cramer-Rao, Chapman-Robbin's and Bhattacharya bounds, BLUE of parametric functions, Efficiency, Consistency, Weak and strong consistency, Marginal and joint consistent estimators, Equivariance, Pitman estimators.

Module-III

Methods of estimation: Methods of moments, Maximum likelihood, Minimum chi square and its modification, Least square estimation, Properties of maximum likelihood estimators, CramerHuzurbazar Theorem, Likelihood equation - multiple roots, Iterative methods, E.M Algorithm.

Module-IV

Basic elements of Bayesian Inference, Loss function, Prior distribution, Bayes Theorem, Posterior distributions, Bayes risk, Bayes principle, Bayes estimators, Minimax estimators, Metropolis-Hastings algorithm, Gibbs sampler, MCMC method.

Text Books:

1. E.L.Lehmann (1998) Theory of Point Estimation, John Wiley and Sons.
2. V.K.Rohatgi and A.K.L. Saleh (2001) An Introduction to Probability and Mathematical Statistics, Wiley.
3. B.K. Kale (1999) A First Course in Parametric Inference, Narosa Publishing Company.
4. Robert C.P. and Casella, G (1999) Monte Carlo Statistical Methods, Springer Verlag.

Reference Books:

1. Rao, C.R. (1973) Linear Statistical Inference and its Applications, Wiley.
2. Casella, G and Berger, R.L (2002) Statistical Inference, Second Edition, Thompson-Duxbury Press.
3. Mukhopadhay, P. (1999) Mathematical Statistics, New Central Book Agency Pvt. Ltd.

STA10802: PROBABILITY THEORY – II

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
1. Employ Inversion formula, Uniqueness theorem	Apply
2. Illustrate Convergence of distribution function characteristic functions, and moments.	Apply
3. Define Covergence of series of independent random variables	Understand
4. Describe different forms of Central limit theorems	Understand
5. Define Conditional expectation and conditional probability	Understand
6. Demonstrate Randon-Nikodym Theorem and its applications.	Apply

Module-I

Characteristic functions**:** Definition and simple properties, Inversion formula, Uniqueness theorem, Characteristic function and moments, Bochner's Theorem (Statement only), Convergence of distribution function: Weak convergence, Convergence of distribution functions and characteristic functions, Convergence of moments.

Module-II

Laws of Large Numbers**:** Covergence of series of independent random variables, Kolmogorov's inequality, Three series theorem, Weak law of large numbers (Kninchine's and Kolmogorov's), Kolmogorov's strong law of large numbers, Glivenko-Cantelli theorem, Kolmogorov's law of iterated logarithms (without proof).

Module-III

Limit Theorems**:** Central limit theorems for i.i.d random variables, Lindberg-Levy and Liaponov's CLT, Lindberg-Feller CLT, Infinitely divisible distributions--definition, elementary properties and examples, Canonical representation (without proof).

Module-IV

Conditioning: Conditional expectation and its properties, Conditional probabilities, Randon-Nikodym Theorem (Statement only) and its applications. Martingales, Submartingales,Martingale convergence theorem, Decomposition of submaritingales.

Text Books:

1 Bhat, B.R. (2011) Modern Probability Theory, Second edition, Wiley Eastern, Chapters 7, 8, 10, 11, 12.

2 Laha. R.G. and Rohatgi V.K. (1979) Probability Theory, John Wiley, Relevant sections of Chapters 2, 4, 6.

Reference Books:

1 Billingsley, P. (1986) Probability and Measure, Second edition, John Wiley

2 Feller, W. (1976) An Introduction to Probability Theory and its Applications, Volume II Wiley Eastern.

3 Hoffmann - Jorgensen J. (1994) Probability with a view towards Statistics, Chapman & Hall.

4 Loeve M. (1977) Probability Theory, Volume I, Fourth edition, Springer-Verlag 5. Loeve, M. (1978) Probability Theory, Volume II, Fourth edition, Springer-Verlag.

5 Rohatgi, V.K. and Saleh, A.K.E. (2001) An Introduction to Probability and Statistics, John Wiley & Sons.

6 Resnich, S. I. (2005). A Probability Path. Birhauser, Springer.

STA10803 : STOCHASTIC PROCESSES

Course Outcomes (CO) After completion of this course the students will be able to	Cognitive level
1.Understand the classifications of random processes and concepts such as strict stationarity, wide-sense stationary and ergodicity	Understand
2.Classify the sates of a Markov chain and apply ergodic theorem for finding limiting distribution on states	Understand
3.Understand and apply Poisson, birth-death, renewal Processes and Brownian motion	Apply
4.Describe and use the recurrence relation for generation sizes in Branching Process and determine the probability	Evaluate

Module-I

Markov Chains: Definition, Examples and classification, Discrete renewal equation and basic limit theorem, Absorption probabilities, Criteria for recurrence.

Module-II

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.

Module-III

Galton-Watson branching processes, generating function, Extinction probabilities, Continuous time branching processes, Extinction probabilities, Branching processes with general variable life time.

Module-IV

Renewal equation, Renewal theorem, Applications, Generalizations and variations of renewal processes, Applications of renewal theory, Brownian motion.

Text Books:

1. Karlin..S. and Taylor, H.M. (1975) A First Course in Stochastic Processes, second edition, Academic Press, Relevant sections of Chapters 1, 2, 3, 4, 5 and 8.
2. Bhat, B.R. (2002) Stochastic Processes, second edition, New Age Publication.

Reference Books:

1. Feller, W. (1965, 1968), An Introduction to Probability Theory and its Applications, Volume I and II, Wiley Eastern.
2. Bhat, U.N. (1984) Elements of Applied Stochastic Processes, John Wiley.
3. Cinlar, E. (1975) Introduction to Stochastic Processes, Prentice Hall.
4. Cox, D.R. (1962) Renewal Theory, Methuen.
5. Ross, S. (1996) Stochastic Processes, Second edition, John Wiley
6. Medhi, J. (1994) Stochastic Processes, Second edition, Wiley Eastern.
7. Basu, A.K. (2002) Elements of Stochastic Processes, Narosa Publications.
8. Bhat, U.N. and Gregory Miller (2003) Elements of Applied Stochastic Process, John Wiley.
9. Hoel, P. G., Port, S. C and Stone, C. J. (1986). Introduction to Stochastic Processes. Waveland Press.

STA10804: PRACTICAL – I

Course Outcomes (CO) After completion of this course the students will be able to	Cognitive level
1.Apply the different sampling methods for designing and selecting a sample from a population	Apply
2.Apply the methods of generating random numbers from different probability distributions and its goodness-of-fit using R software	Apply
3.Formulate and solve problems which involve setting up stochastic models.	Evaluate
4.Understand the notion of a parametric models, point and interval estimation of the parameters of those models using real data	Understand
5.Apply topics related to the Elective in the Semester II using real data sets and interpretation of the results.	Apply

Practicals based on topics covered in

STA10704 : Sampling Theory and Methods

STA10801 : Statistical Inference I

STA10803 : Stochastic Processes

STA10805 : Elective II

STA1080 -: ELECTIVE - II
STA1080 -: ELECTIVE – III

SEMESTER IX

STA10901: STATISTICAL INFERENCE – II

Course Outcome (C.O) After completion of this course the students will be able to	Cognitive level
1.Summarize the testing problem in 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	Analyze
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.Distinguish non-parametric confidence interval and bootstrap Confidence intervals Analyze

8.Examine the non-parametric alternatives for each parametric test. Analyze

Module-I

Tests of hypotheses, Formulation of problem, Null and alternative hypotheses, Size of a test, two kinds of errors, Simple and composite hypotheses, Randomized and non-randomized tests, Power of a test, Most powerful test, Neyman-Pearson lemma and its generalization, Monotone likelihood ratio property, UMP tests, Unbiased tests and UMPU tests with examples., Multiple hypothesis testing, False discovery rate.

Module-II

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.

Module-III

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 tests, Construction of sequential probability ratio tests with examples.

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Module-IV

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, ManWhitney U-test, Non-parametric confidence intervals, Bootstrapping confidence intervals, P-P Plot and Q-Q plot, Kendall's tau, Tests for independence and homogeneity.

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Text Books:

1 Lehmann, E.L. (1998) Testing Statistical Hypothesis, John Wiley.

2 Wald, A. (1947) Sequential Analysis, Doves

3 Gibbons, J.K. (1971) Non-Parametric Statistical Inference, McGraw Hill

4 Rohatgi, V.K. and Saleh, A.K.E. (2001) An Introduction to Probability and Statistics, John Wiley and Sons.

5 Kale, B.K. (1999) A First Course in Parametric Inference, Narosa Publications.

Reference Books:

1. Rao, C.R. (1973) Linear Statistical Inference and its Applications, Wiley.

2. Casella, G and Berger, R.L (2002) Statistical Inference, Second Edition, Thompson-Duxbury Press.
3. Rajagopalan, M and Dhanavanthan, P. (2012). Statistical Inference.
4. Dixit, U. J. (2016). Examples in Parametric Inference with R, Springer.

STA10902: MULTIVARIATE ANALYSIS

Course Outcome (CO) After completion of this course the student should be able to	Cognitive level
1.Describe Multivariate data and its preliminary analysis	Understand
2.Interpret multivariate normal distribution (MVN)	Apply
3.Examine Wishart distribution and its	Analyze
4.Explain Hotelling'sT^2 and Mahalanobis D^2	Understand
5.Outline various multivariate testing problems	Analyze
6.Evaluate the above testing problems	Apply
7.Explain classification problem	Understand
8.Describe Principal component analysis (PCA)	Understand

Module-I

Multivariate data, preliminary analysis, notion of multivariate distributions, multivariate normal distribution, marginal and conditional distributions, characteristic function, estimation of mean vector and covariance matrix.

Module-II

Distribution of rectangular co-ordinates, Wishart distribution and its properties, distribution of simple, partial and multiple correlations based on samples from normal population, Hotelling'sT^2 and Mahalanobis D^2 statistics, properties of T^2 and D^2, multivariate Fisher-Behren's problem.

Module-III

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. **Module-IV**

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; principal component analysis- definition, properties and ML estimation; canonical variables, canonical correlation.

Text Books:

1. Anderson, T.W. (1984) An Introduction to Multivariate Statistical Analysis, John Wiley.
2. Johnson, R.A. and Wichern, D.W. (1990) Applied Multivariate Statistical Analysis, Prentice Hall.

Reference Books:

1. Seber, G.A.F. (1977) Multivariate Observations, Wiley.
2. Giri, N., Multivariate Statistical Inference, Academic Publishers.
3. Morrison, D.F. (1976) Multivariate Statistical Methods, John Wiley.
4. Rao, C.R. (1973) Linear Statistical Inference and the Application, Wiley.
5. Rancher, A.C. (1995) Methods of Multivariate Analysis, John Wiley.

STA10903: APPLIED REGRESSION ANALYSIS

Course Outcome (CO)	**Cognitive level**
After completion of this unit the student should be able to	
1. Identify a linear and nonlinear regression problem	Apply
2. Model a data using an appropriate Regression model	Analyze
3. Identify and interpret a regression model.	Understand
4. Examine model diagnostics	Analyze
5. Identify a Non parametric Regression problem	Analyze
6. Apply Non Parametric Regression techniques	Apply

Module-I

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.(12+4+4hrs)

Module-II

Residual analysis, Departures from underlying assumptions, Effect of outliers, Collinearity, Non-constant variance and serial correlation, Departures from normality, Diagnostics and remedies.

Module-III

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 nonparametric regression.

Module-IV

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**.**

Text Books:

1 Montgomery, D.C., Peck, E.A. and Vining, G.G. (2001) Introduction to Regression Analysis, Third 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,

Reference Books:

1 Searle, S.R. (1971) Linear models, John Wiley & Sons, Inc.

2 N.Draper and H. Smith (1986) Applied Regression Analysis – John Wiley & Sons.

3 Fox, J. (1984) Linear Statistical Models and Related methods, John Wiley, Chapter 5.

4 Christensen, R. (2001) Advanced Linear Modeling, Chapter 7.

5 B.Abraham and Ledotter, J. (1983) Statistical Methods for Forecasting, John Wiley & Sons.

STA10904: PRACTICAL - II USING SPSS/MATLAB

Course Outcome (CO) **After completion of this course the students will be able to**	**Cognitive level**
1.Understand various tools in SPSS/Matlab	Understand
2.Apply different statistical testing problems using real data sets and interpretation of the results	Analyze
3.Apply different multivariate techniques using real data sets and interpretation of the results	Analyze
4.Apply different regression techniques using real data sets and interpretation of the results	Evaluate
5.Apply topics related to the Elective in the Semester III using real data sets and interpretation of the results.	Apply

Practicals based on topics covered in

STA10901 ;Statistical Inference II

STA10902 :Multivariate Analysis

STA10903 :Applied Regression Analysis

STA10905 : Elective IV

STA1090 - - : ELECTIVE – IV

STA1090 - - : ELECTIVE - V

SEMESTER X

STA11001: DESIGN AND ANALYSIS OF EXPERIMENTS

Course Outcome (CO) After completing the course, the student should be able to	Cognitive level
1.Understand the basic principles and guidelines of Design of experiments	Apply
2.Design and analyze CRD RBD,LSD and Greaco LSD	Apply
3.Apply incomplete block designs in designing experiments and analyze them	Analyze
4.Understand and apply the factorial designs and its various versions	Apply
5.Apply Response surface methodology understanding various aspects involved in it.	Apply

Module-I

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 effects and Random effects model. Model adequacy checking, CRD, RBD and Latin Square designs, Analysis of co-variance for completely randomized and randomized block designs. Analysis of experiments with missing observations.

Module-II

Incomplete Block Designs: Balanced Incomplete Block designs, Construction of BIB Designs, Analysis with recovery of inter-block information and intra-block information. Partially balanced incomplete block designs, Analysis of partially balanced incomplete block designs with two associate classes, Lattice designs.

Module-III

2^n Factorial experiments. Analysis of 2^n factorial experiments. Total confounding of 2^n designs in 2^p blocks. Partial confounding in 2^p blocks. Fractional factorial designs, Resolution of a design, 3^n factorial designs. Split plot design and strip plot design (outline only).

Module-IV

Response surface designs - orthogonality, rotatability blocking and analysis - Method of Steepest accent, Models, properties and Analysis.

Text Books:

1.Montgomery, D.C. (2001)) Design and Analysis of Experiments, John Wiley.

2.Das M N and Giri N.C. (1979) Design and Analysis of Experiments, second edition, Wiley.

3.Hinkleman and Kempthrone, C. (1994) Design and Analysis of Experiments-I, John Wiley.

Reference Books:

1. Joshi D.D. (1987) Linear Estimation and Design of Experiments, Wiley Eastern.

2. Chakrabarti, M.C. (1964) Design of experiments, ISI, Calcutta.

STA1002: PRACTICALS - III USING SAS/R AND VIVA-VOCE

Course Outcome (CO) After completion of this course the students will be able to	Cognitive level
1.Understand the various computational techniques using R.	Understand
2.Develop programming skill to meet the given Scientific objective	Analyze
3.Apply different DoE techniques using real data sets and interpretation of the results	Apply
4.Apply topics related to the Elective I in the Semester IV using real data sets and interpretation of the results	Apply
5.Apply topics related to the Elective II in the Semester IV using real data sets and interpretation of the results	Apply

Practical based on topics covered in

STA11001 : Design and Analysis of Experiments.

Elective IV, Elective V, Elective VI.

STA11003: Project

STA1100 - -: Elective VI

STA1100- -: Elective VII

STA1100- -: Elective VII

LIST OF ELECTIVES

Course Name-STA10705: Data Analytics using R

Course Outcome (CO) After completion of this course the students will be able to	**Cognitive level**
1.Develop a scientific computing environment using R	Evaluate
2.Identify the use of R software to meet the given scientific objective	Analyze
3.Identify the use of various packages in R	Analyze
4.Write an efficient program using R to perform routine and specialized data manipulation /management and analysis tasks	Evaluate

Module-I
Introduction to statistical software R, Using R as a calculating environment, Arithmetic variables, Functions, Vectors, Expressions and assignments, Logical expressions, manipulating vectors, matrices, importing of files.

Types of data, Scale of measurement, Data objects in R, Graphical summaries of data-Bar chart, Pie chart, Histogram, Box-plot, Stem and leaf plot, Frequency table, Plotting of probability distributions and sampling distributions, P-P plot, Q-Q Plot, Computations of descriptive statistics measures. Inference from bivariate data-Scatter plot, Correlation and Regression.

Module-II
Basic programming, Branching with if, Looping with for, Looping with while, Vector-based programming, Program flow, Pseudo-code, Basic debugging, Programming with functions, Vectorized functions, Optional arguments and default values, Vector based programming using functions, Recursive programming, Debugging functions, Data frames, Lists, Use of apply group of functions.

Module-III
Simulation, Congruential generators, Seeding, Random Number Generation- Basic principles of Random number generation, Inversion method, Accept-reject method, Random number generation from Binomial, Poisson Uniform, Exponential, Cauchy and Normal, Rejection with exponential envelope, Box-Muller algorithm.

Module-IV

Statistical Inference Problems Using R-Estimation and confidence intervals-Point estimates of normal mean, confidence interval for normal mean with known and unknown standard deviation. Confidence interval for standard deviation. Confidence interval for proportion.

One sample t-test, two sample t-test, paired t-test, test on standard deviation (chi-square test).

Text Book:

1.Jones, O., Maillardet. R. and Robinson, A. (2014). Introduction to Scientific Programming andSimulation Using R. Chapman & Hall/CRC, The R Series.

2.Crawley, M, J. (2012). The R Book, 2nd Edition. John Wiley & Sons.

Reference Books:

1. Chambers, J. M. (2008). Software for Data Analysis-Programming with R. Springer-Verlag, New York.

2. Jammalamadaka, S. R. (2007). Essential Statistics with python and R.Kendal Hunt publishing.

STA10706: Statistical Computing

Course Outcome (C.O) After completion of this course the students will be able to	Cognitive level
1. Understand commonly used R codes for statistical work.	Understand
2. Identify the use of various packages in R.	Analyze
3. Apply R software to meet the given scientific objective.	Apply
4. Write an efficient R program to solve the given scientific problem.	Evaluate

Module-I

Introduction to statistical software R, Data objects in R, Vectors, manipulating vectors, matrices, importing of files. Input and outputs: Text - Input from a file - Input from the keyboard - Output to a file. Computations of descriptive statistics measures. Expressions and assignments, logical expressions. RGraphics- lattice & 3D-plots. Histogram, Box-plot, Stem and leaf plot, Scatter plot, Plot options; Multiple plots in a single graphic window, frequency table, Plotting of probability distributions and sampling distributions, Controlling Loops- For, repeat, while, if , if else etc.

Module-II

Programming with functions: Functions - Scope and its consequences - Optional arguments and default values - Vector-based programming using functions - Recursive programming - Debugging functions Sophisticated data structures - Factors -Dataframes -Lists - The apply family.

Graphics parameters: par -Graphical augmentation - Mathematical typesetting - Permanence -Grouped graphs: lattice - 3D-plots.

Module-III

Numerical methods- Root-finding - Fixed-point iteration -The Newton-Raphson method - The secant method - The bisection method - Numerical integration - Trapezoidal rule - Simpson's rule - Adaptive quadrature.

Module-IV

Simulation: Simulating iid uniform samples, Congruential generators, Seeding, Simulating discrete random variables, Inversion method for continuous random variables, Rejection method, generation of normal variates: Rejection with exponential envelope, Box-Muller algorithm.

Text Books:

1.Owen Jones, Robert Maillardet, Andrew Robinson, (2014) . Introduction to Scientific Programming and Simulation Using R, *Chapman & Hall/CRC The R Series,*

2.Alain F. Zuur, Elena N. Ieno, and Erik Meesters (2009) A Beginner's Guide to R, Springer, ISBN: 978-0-387-93836-3.

3.Phil Spector (2008) Data Manipulation with R, Springer, New York, ISBN 978-0-387-74730-9.

4.Christian Heumann, Michael Schomaker, Shalaf (2016). Introduction to statistics and data analysis. Springer.

Reference Books:

1.Gotifried, B.S. (2011) Programming with C, Schaum's Series,Third Edition, Tata McGraw Hill.

2.Mullishi Hank, Cooper, H.L. (1992) The spirit of C - An introduction to modern programming, Jaico Publishing House.

3.Kundu, D. and Basu, A. (2004) Statistical computing – existing methods and recent developments, Narosa publishing house, New Delhi.

4.Monahan, J.F. (2001) Numerical methods of statistics, Cambridge University Press.

5.Aitkinson, K.E. (1989) An introduction to numerical analysis, John Wiley & Sons, Singapore.

STA10805 :STATISTICS FOR NATIONAL DEVELOPMENT

Course Outcome (CO)	Cognitive level
After completion of this course the students will be able to	
1. Explain the concept of economic development, growth in per capita income and distributive justice	Understand
2. Define the indices of development like Human development index etc.	Understand
3. Estimate national income through income	

	and expenditure approaches	Apply
4.	Measure inequality in incomes, and measure poverty through measures of incidence and intensity combined.	Analyze
5.	Define components of Time series Determine the trend, analyze seasonal	Remember
6.	Fluctuations, construct seasonal indices Measure cyclical movement	Analyze

Module-I

Demographic methods:- Sources of demographic data - census, register, adhoc survey, hospital records, demographic profiles of Indian census; Measurement of mortality and life tables - crude, death rates, infant mortality rates, death date by cause, standardized death rate; Complete life tables – its main features, mortality rate and probability of dying, use of survival tables; Measurement of fertility - crude birth rate, general fertility rate, total fertility rate, gross reproduction rate, net reproduction rate; Population growth in developing and developed countries; Population projection using Leslie metric; Labour force projection.

Module-II

Economic statistics:- Index number - its definition, price relatives and quantity or volume relatives, link and chain relatives, consumer price index; Demand analysis - static laws of demand and supply, price elasticity of demand, analysis of income and allied size distribution - Pareto distribution, graphical test, fitting of Pareto's law, log normal distribution and its properties, Lorenz curve and estimation of elasticity; Gini coefficient.

Module-III

Economic development, growth in per capita income and distributive justice, indices of development; Human Development Index, Estimation of national income - product approach, income approach and expenditure approach; Measuring inequality in incomes, poverty measurement - measures of incidence and intensity combined; Time Series:-components of time series, determination of trend, analysis of seasonal fluctuations, construction of seasonal indices, measurement of cyclic movement, random component in time series, smoothing methods.

Module-IV

Introduction to Indian and International Statistical System - role, function activities of Central and State Statistical Organizations; Organization of large scale sample surveys; Role of National sample survey organization; General and special data dissemination systems; Principal publications containing such statistics on the topics - population, agriculture industry, trade, price, labour and employment transport and communications, and finance; Educational and Psychological statistics:-Scaling individual test items, scaling of scores on a test, different types of scores and scaling, scaling of ranking and rating in terms of normal curve, Reliability of test scores, Rulon and Kuder Richardson methods, Reliability of a test, validity, comparison between reliability and validity, Intelligence coefficient.

Reference Books:

1 Basic Statistics Relating to Indian Economy (CSO), 1990 - Current Indian Statistics

2 Cox PR (1957) Demography, Cambridge University Press

3 Croxton F E and Crowder D J (1967) Applied General statistics, Prentice - Hall India.

4 Guide to current Indian Official Statistics CSO, Govt. of India, New Delhi

5 Guide to official Statistics (CSO) -1990

6 Kendall, M.G. and Stuart, A. (1966). The Advanced Theory of Statistics, Charles Griffin

7 Keyfitz, N. (1977) Applied Mathematical Demography - Springer Verlag

8 Mukhopadhyay, P Applied Statistics, Books and Allied (P) Ltd

9 Pollard, A H, Yusuf , F and Pollard, G.N. (1998) Demographic Techniques

10 Saluja M.P, Indian Official Statistical Systems, Statistics Publishing Society, Calcutta

11 Sen, A. (1997) : Poverty and inequality

12 Statistical System in Indian (CSO) 1995

13 UNESCO : Principles for Vital Statistics system, Series M-12

STA10806: RELIABILITY MODELING AND ANALYSIS

Course Outcome (CO)	Cognitive Level
After completing the course, the student should be able to	
1. Understand the various concepts and different notions of ageing used in Reliability analysis and their inter relations.	Describe
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 distributions	Evaluate
3. Understand and discover the system reliability using the concept of structure functions	Understand
4. Understand the concepts like positive dependency and various measures of dependence viz - RCSI, LCSD, PF 2 , WPQD and their inter relations.	Evaluate
5. Estimate the reliability function for complete and censored samples through the maximum likelihood estimation,	Evaluate
6. Estimate the reliability function for complete and censored samples through Uniformly minimum variance unbiased estimation	Evaluate
7. Estimate the reliability function for complete and censored Samples through the Bayesian Estimation.	Evaluate

Module-I

Structure functions, Coherent Systems, Basic concepts in reliability: Failure rate, mean, variance and percentile residual life, identities connecting them; Notions of ageing - IFR, IFRA, NBU, NBUE, DMRL, HNBUE, NBUC etc and their mutual implications; TTT transforms and characterization of ageing classes.

Module-II

Non monotonic failure rates and mean residual life functions, Study of life time models viz. exponential,Weibull, lognormal, generalized Pareto, gamma with reference to basic concepts and ageing characteristics; Bath tub and upside down bath tub failure rate distributions.

Module-III

Reliability systems with dependent components:-Parallel and series systems, k out of n systems, ageing properties with dependent and independents components, concepts and measures of dependence in reliability - RCSI, LCSD, PF 2 , WPQD.

Module-IV

Reliability estimation using MLE - exponential, Weibull and gamma distributionsbased on censored and non censored samples; UMVUE estimation of reliability function; Bayesian reliability estimation of exponential and Weibull models.

Text Books:

1.Lai, C.D and Xie, M. (2006): Stochastic ageing and dependence in reliability (Relevanttopics) Springer.

2.Sinha S K (1986) Reliability and Life Testing, Wiley Eastern.

3.Barlow, R.E. and Proschan, F. (1975) Statistical Theory of Reliability and Life Testing, Holt, Reinhart and Winston.

Reference Books:

1. Marshall, A.W. and Olkin, I. (2007) Life Distributions, Springer
2. Galambos, J. and Kotz, S. (1978) Characterization of Probability distributions,Springer
3. Lawless, J.F. (2003) Statistical Models and Methods for Life Data, Wiley.

STA10905: TOPICS IN STOCHASTIC FINANCE

Course Outcome (CO) After completion of this course the students will be able to	Cognitive level
1.Define the terms: interest rate, options, pay-off, arbitrage, geometric Brownian motion, mean reversion, etc.	Remember
2.Describe and prove arbitrage theorem, Black Scholes theorem	Evaluate
3.Distinguish call and put options.	Understand
4.Analyze portfolios via utility functions.	Analyze
5.Apply CAPM.	Apply
6.Assess the value at risk.	Evaluate

7.Describe exotics by simulation.	Understand
8.Employ and fit AR models for log prices	Apply

Module-I
Interest rate and Present value analysis, rate of return, Continuously varying interest rate. Options, Pricing contracts via arbitrage, Arbitrage theorem, single and multi-period binomial model.

Module-II
Geometric Brownian motion, The Black-Scholes formula, Properties of the Black-Scholes option cost, the delta hedging arbitrage strategy, Derivatives, Call options on dividend-paying securities, Pricing American put options.

Module-III
Adding jumps to geometric Brownian motion, Estimating the volatility parameter, Valuing investments by expected utility, The portfolio selection problem, Value at risk and conditional value at risk, The Capital Assets Pricing Model.

Module-IV
Exotic Options, Barrier options, Asean and look back options, Pricing exotic options by simulation, Pricing with nonlinear payoffs, Approximation via multiperiod binomial models, Crude oil data, Autoregressive moving average models for returns, Mean reversion.

Text Book:

1.Sheldon M. Ross (2003).An Elementary Introduction to Mathematical Finance. Cambridge University Press.

Reference Books:

1 A.N. Shiryave (1999). Mathematical Finance, Theory and Practice, World Scientific.

2 David Ruper (2004). Statistics and Finance- An Introduction, Springer International Edition.

3 Fima C. Klebener (1997). Introduction to Mathematical Finance. World Scientific 4. John C. Hull (2008). Options, Futures and other derivatives. Pearson Education India.

STA10906: OPERATIONS RESEARCH II

Course Outcome (CO)	**Cognitive level**
After completion of this course the student should be able to	
1.Examine the properties of linear programming problem	Analyze
2.Solve different types of LPP	Apply
3.Solve LPP using duality	Apply
4. Employ transportation and assignment problems	Apply
5. Solve non-linear programming problems	Apply
6. Explain quadratic and convex programming problems	Understand
7. Examine deterministic and probabilistic inventory models	Analyze
8. Employ inventory models in real situations	Apply

Module-I

Linear programming:- convex sets and associated theorems, graphical method, definition of linear programming problem, properties of a solution to the linear programming problem, generating extremepoint solutions, simplex computational procedure, artificial variables technique - big M method, two phase method; Revised simplex method.

Module-II

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).

Module-III

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.

Module-IV

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).

Text Books:

1. Gass S.I. (1985) Linear Programming - methods and applications, Fifth edition, McGraw Hill, USA, Chapters 2-7.
2. KantiSwarup, Gupta, P.K. and Man Mohan (2001) Operations Research, Ninth edition, Sultan Chand & Sons, Chapters 3, 4, 10, 11 & 24.
3. Taha H.A. (2007) Operations Research - An introduction, Eighth edition, Prentice-Hall of India Ltd., Chapters 11, 14 & 15.

Reference Books:

1. Ravindran A, Philips D.T and Soleberg J.J. (1997) Operation Research - Principles and Practice, John Wiley & Sons.
2. Sinha, S.M. (2006) Mathematical programming theory and methods, Elsevier, a division of Reed Elsevier India Pvt. Ltd., New Delhi.
3. Paneerselvam, R. (2008) Operations Research, Second edition, Prentice Hall of India Pvt. Ltd., New Delhi.

STA11004: STATISTICAL QUALITY ASSURANCE

Course Outcome (CO) **Cognitive level**

After completing this course the student should be able to

1.	Apply different statistical quality control techniques including various types sampling plans for attributes and measure the performance of these plans.	Apply
2.	Explain and design various types of control charts, design control charts Distinguish between them.	Apply
3.	.Explain acceptance sampling by variables, Sampling Plans for a single and double specification limits with known and unknown variance, Sampling plans with double specification limits.	Apply
4.	Compare sampling plans by variables and attributes and Continuous sampling plans I, II & III	Evaluate

Module-I

Quality and quality assurance, Methods of quality assurance, Introduction to TQM and ISO 9000 standards, statistical quality control: Acceptance sampling for attributes, Single sampling, Double sampling, Multiple and sequential sampling plans, Measuring the performance of these plans.

Module-II

Control charts, Basic ideas, designing of control charts for the number of non-conformities and fraction nonconformities, mean charts, Median charts, Extreme value charts, R-charts, and S-charts, ARL, Economic design of Shewarts control charts.

Module-III

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, Continuous sampling plans I, II and III.

Module-IV

Process capability studies, Statistical aspect of six sigma philosophy, Lean concepts, Control charts with memory - CUSUM charts, EWMA-mean charts, OC and ARL for control charts, The Taguchi Method: The Taguchi philosophy of Quality, Loss functions, SN ratios, Performance measures, Experimental design in Taguchi Methods: Orthogonal arrays and linear graph, Estimation of effects, Parameter Design.

Text Books:

1 Montgomery, R.C. (1985). Introduction to Statistical Quality Control, Fourth edition,Wiley.

2 Mittag, H.J. & Rinne, H. (1993) Statistical Methods for Quality Assurance, Chapman &Hall, Chapters 1, 3 and 4,15

3 The ISO 9000 book, Second Edition, Rabbit, J T and Bergle, PA Quality resources,Chapter-I4. Schilling, E.G. (1982) Acceptance Sampling in Quality Control, Marcel Dekker.

5. AmitavaMitra - Fundamentals of Quality Control and Improvement – PearsonEducation Asia 2001 – Chapter 12 (relevant parts)

Reference Books:

1 Duncan, A.J. (1986) Quality control and Industrial Statistics.

2 Grant E.L. and Leaven Worth, R.S. (1980) Statistical Quality Control, McGraw Hill.

3 Chin-Knei Cho (1987) Quality Programming, John Wiley.

STA11005: TIME SERIES ANALYSIS

Course Outcome (CO)	Cognitive level
After completion of this course the students will be able to	
1. Define time series in time and frequency domain.	Remember
2. Assess the stationarity of time series and its decomposition.	Evaluate
3. Identify suitable ARMA models for the stationary component of the given time series.	Analyze
4. Estimate the parameters of the identified models.	Analyze
5. Discuss the validity of the model by residual analysis.	Understand
6. Prediction by MMSE methods.	Evaluate
7. Analyze Spectral density and periodogram.	Analyze
8. Analyze time series in a state space set up.	Analyze
9. Compute Smooth and filter by Kalman algorithm.	Apply
10. Identify a model for the given time series.	Analyze

Module-I

Characteristics of time series: Time series as a discrete parameter stochastic process, Auto-correlation (ACF) and cross correlations, Stationary time series, Estimation of autocorrelations. Classical regression in time series context, exploratory data analysis, smoothing methods for time series. World representation of linear stationary processes. (15 hours)

Module-II

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-III

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. (15 hours)

Module-IV

State space models: Filtering, smoothing and forecasting using state space models, Kalman smoother, Maximum likelihood estimation, Missing data modifications. (15 hours).

Text Books:

1 Shumway, R. H and Stoffer, D. S. (2006). Time series Analysis and its Applications. Springer.

2 Box, G. E. P. Jenkins, G. M. and Reinsel, G. C. (1994). Time Series Analysis: Forecasting and Control, Pearson Education.

3 Brockwell, P.J and Davis R.A. (2006) Time Series: Theory and Methods, 2nd edn. Springer-Verlag.

Reference Books:

1 Abraham, B. and Ledolter, J.C. (1983) Statistical Methods for Forecasting, Wiley.
2 Anderson, T.W (1971) Statistical Analysis of Time Series, Wiley.
3 Fuller, W.A. (1978) Introduction to Statistical Time Series, John Wiley.
4 Kendall, M.G. (1978) Time Series, CharlerGraffin.
5 Tanaka, K. (1996) Time Series Analysis, Wiley Series.
6 Chatfield, C. (2004) The Analysis of Time Series - An Introduction, Sixth edition, Chapman and Hall.

STA11006: LIFETIME DATA ANALYSIS

Course Outcomes (CO)	Cognitive level
After completion of this course the student should be able to	
1. Understand the basic concepts and ideas of survival analysis.	Understand
2. Examine the properties and methods for standard survival time distributions.	Analysis
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

Module-I

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.

Module-II

Nonparametric Estimation of Basic Quantities for Right Censored and Left Censored Data - Estimators of the Survival and Cumulative Hazard Functions for Right Censored Data, PointwiseConfidence Intervals for the Survival Function (without derivation), Estimators of the Survival Function for Left-Truncated and Right-Truncated Data; Estimation of the Survival Function for Left, Estimating the Hazard Function, Hypothesis Testing - One-Sample Tests, Tests for Two or More Samples.

Module-III

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.

Module-IV

Inference for Parametric Regression Models - Exponential, Weibull and Log Logistics; Multiple Modes of Failure – Basic Characteristics and Model Specification, Likelihood Function Formulation, Nonparametric Methods.

Text Books:

1 Klein J.P. and Moeschberger M.L. (2003) Survival Analysis - Techniques for censored and truncated data, Second Edition, Springer-Verlag , New York,

2 Lawless J.F (2003) Statistical Models and Methods for Lifetime Data, Second Editon, John Wiley & Sons, Relevant Sections of the Chapters 9.

Reference Books:

1 Kalbfleisch J.D and Prentice, R.L. (2002) The Statistical Analysis of Failure Time Data, Second Edition, John Wiley & Sons Inc.

2 Hosmer Jr. D.W and Lemeshow S (1999) Applied Survival Analysis - Regression Modelling of Time to event Data, John Wiley & Sons. Inc.

3 Nelson. W (2003) Applied Life Data Analysis.

4 Miller, R.G. (1981) Survival Analysis, John Wiley.

5 Deshpande, J .V. and Purohit, S. G. (2006). Lifetime Data: Statistical Models and Methods. World Scientific.

STA11007: APPLIED MULTIVARIATE STATISTICAL ANALYSIS

After completion of this course the student should be able to

Course Outcome (CO)	**Cognitive level**
1.Distinguish multivariate data and its preliminary analysis	Understand
2.Examine properties of principal component analysis	Analyze
3. Apply PCA and canonical variates to real data	Apply
4. Analyze factor model	Understand
5. Illustrate the factor analysis	Apply
6. Outline different clustering and similarity techniques	Understand
7. Apply various clustering and similarity techniques	Apply
8. Infer multivariate data using MANOVA	Apply

Module-I

Multivariate Data, Types and preliminary methods of analysis, Principal components Analysis: - population principal components, summarizing sample variation by principal components, graphing the principal components, large sample inference, monitoring quality with principal components; Canonical correlation analysis: - canonical variates and canonical correlations, interpreting the population canonical variables, the sample canonical variates and sample canonical correlations.

Module-II

Factor analysis: - orthogonal factor model; methods of estimation, factor rotation, factor scores, perspectives and a strategy for factor analysis.

Module-III

Cluster analysis: - similarity measures, hierarchical clustering methods, non-hierarchical clustering methods; Distance methods: - multidimensional scaling, correspondence analysis.

Module-IV

Comparison of several multivariate population means (one-way MANOVA), simultaneous confidence intervals for treatment effects, two-way multivariate analysis of variance; profile analysis; Repeated measures designs and growth curves, path analysis.

Text Books:

1 Johnson, R.A. and Wichern, D.W. (2007) Applied Multivariate Statistical Analysis, PHI Learning Private Ltd, New Delhi, Sixth edition, Relevant sections from Chapters 1, 6, 8, 9, 10 & 12.

2 Dillon, W.R. and Goldstein, M (1984) Multivariate Analysis, John Wiley, Relevant sections from Chapter 12.

Reference Books:

1. Seber G.A.F. (1983) Multivariate Observations, Wiley.
2. Tabachnick, B.G. and Fidell, L.S. (2018) Using multivariate statistics, Sixth edition,

   Pearson India EducationServices Pvt Ltd, India.
3. Gnandesikan, R., Methods of Statistical Data Analysis of Multivariate Observations, Wiley.
4. Jambu, M and Lebeaux M.O., Cluster Analysis and Data Analysis.
5. Lebart, Lmorinean, A. and Warwick K.M., Multivariate Descriptive Statistical Analysis, John Wiley.
6. Davison, Multidimensional Scaling, John Wiley.
7. Morrison D.F., Multivariate Statistical Methods, McGraw Hill.
8. Rencher, A.C. (1995) Methods of Multivariate Analysis, John Wiley.

21-322-0408: STATISTICAL FORECASTING

Course Outcome(C.O)	**Cognitive level**
After completion of this course the students will be able to	
1. Define various types of forecasts and their performance measures.	Remember.
2. Compute forecasts based on regression models.	Apply
3. Compute forecast by simple and double exponential smoothing.	Apply
4. Understand algorithms of Holt-Winters methods for forecasting.	Understand

5. Estimate and forecast seasonal time series.	Evaluate
6. Describe explicit forms of stationary and non-stationary time series derive the models and forecasts.	Evaluate
7. Describe forecast formula for state-space models.	Evaluate
8. Smoothing and filtering by Kalman filters.	Analyze
9. Choose a model and construct forecast formula for a given time series.	Apply

Module-I

Review of linear regression and time series models. Forecasting in constant mean model, Locally constant mean model and simple exponential smoothing.Regression models with time as independent variable, Discounted least squares and general exponential smoothing. Locally constant linear trend model and double exponential smoothing, Prediction intervals.

Module-II

Seasonal time series, Globally constant seasonal models, Locally constant seasonal models, Winters' seasonal forecast procedures (additive and multiplicative), Seasonal adjustment procedures.

Module-III

Forecasts based on stationary ARMA and non-stationary ARIMA models. Transfer function models and forecasting.

Module-IV

State-space models- Filtering, smoothing and forecasting. Kalman filter. Vector ARMA models and Forecasting.

Text Books:

1 Abraham B and Ledolter, J (2005) Statistical Methods for Forecasting, John Wiley and Sons, New York.

2 Shumway, R. H and Stoffer, D. S. (2006). Time series Analysis and its Applications. Springer.

3 Montegomery, D. C., Jennings, C. L. and Kulachi, M. (2008). Introduction to Time series analysis and Forecasting.

Reference Books:

1 Pankratz, A. (1983) Forecasting with univariate Box-Jenkins models, John Wiley Sons, New York

2 Makridakis, S. and Wheelwright, S.C. (1998) Forecasting Methods and Applications, John Wiley and Sons

3 Box, G. E. P. Jenkins, G. M. and Reinsel, G. C. (1994). Time Series Analysis: Forecasting and Control, Pearson Education.

4 Brockwell, P.J. and Davis, R.A. (2013) Introduction to Time Series and Forecasting, second edition, Forth Edition, Springer.

21-322-0409: INFERENCE FOR STOCHASTIC PROCESSES

Course Outcome (CO) After completion of this course the students will be able to	Cognitive level
1.Define relevant optimality criteria for inference in Remember stochastic processes.	
2.Choose suitable method of estimation and test procedure for given process	Evaluate
3.Compute estimates for relevant parametric functions for Markov chains in discrete and continuous time space	Apply
4.Produce the asymptotic properties of the estimators for such processes	Apply
5.Compute the estimates and test statistics for continuous time such as Markov processes Poisson processes, birth-death processes, etc.	Apply
5.Give examples for processes satisfying the regularity conditions under which estimators and test functions behave well.	Understand
6.Identify a suitable stochastic model for the given situation.	Analyze

Module-I

Brief review of basic principles of methods of statistical inference, Inference for the Galton-Watson process, The Markov branching process, Estimation and prediction in Auto regressive process.

Module-II

Inference in discrete Markov chains: Maximum likelihood estimation, Asymptotic properties of estimators, Asymptotic distribution of serial correlation, Tests of hypothesis tests of independence based on serial correlation Bayesian analysis, Inference for an absorbing chain Inverse likelihood estimation of states, Macro model, grouped Markov chains, Estimation in countable state-space Markov chain.

Module-III

Inference in continuous time Markov chains: Inference in finite Markov chains, queuing models, pure birth and death process, Homogeneous and non-homogeneous Poisson processes, Inference for renewal process in relation to reliability applications.

Module-IV

Large sample theory for discrete parameter stochastic process, Estimation, Consistency, Asymptotic normality, Efficiency, Robustness, Maximum likelihood estimation for some optimal asymptotic tests.

Text Books:

1. Basava, I.V. and Prakasa Rao, B.L.S. (1980) Statistical Inference for Stochastic Processes Academic Press Chapters 1-7.

Reference Books:

1. Billingsley, P. (1961) Statistical Inference for Markov Processes, University of Chicago Press.
2. Chung K.L. (1967) Markov Chain with Stationary Transition Probabilities 2nd edition, SpringerVarlag
3. Karr, A.R. (1991) Point Processes and Their Statistical Inference, Marcel Dickker 4. Keiding, N. (1974) Estimation in the Birth Process, Biometrika, 61, 71-80.
4. Keiding, N.(1975) Maximum Likelihood Estimation in the Birth and Death Process, Annals of Statistics, 3,363-372.
5. Rajarshi, M. B. (2013). Statistical Inference for Discrete time Stochastic Processes. Springer.