File Ref.No.Ac.A3/Faculty of Science/2023

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

(Abstract)

Faculty of Science - Revised regulation, curriculum structure and syllabus of 5 - year Integrated M.Sc. (in Biological Sciences/Chemistry/Mathematics/Physics/Statistics) w.e.f. 2023 admission onwards - Proposal placed before Academic Council - Approved- Orders issued - reg

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ACADEMIC A SECTION

No.CUSAT/AC(A).A3/4950/2023 Dated,KOCHI-22,16.11.2023

Read:-Item No. I (a)(1) of the minutes of the meeting of the Academic Council held on 05.08.2023

ORDER

The Academic Council considered along with the recommendations of its standing committee, the Minutes of the Faculty of Science held on 24.07.2023 and resolved to approve the Regulation, Curriculum structure & Syllabus of 5- year Integrated M.Sc. (in Biological Science/ Chemistry/ Mathematics/ Physics/ Statistics) programme submitted by the combined Board of studies in Chemical & Biological Sciences and Physical & Mathematical Sciences.

The provisions for exit after the 3rd year conferring the B.Sc. Degree and exit after 4th year leading to B.Sc Honours degree or B.Sc Honours by Research degree are incorporated.

The revised Regulation, Curriculum structure and the Syllabus (appended) are with effect from 2023 admission onwards.

Orders are issued accordingly.

Dr. Meera V *
Registrar

To:

1. The Dean, Faculty of Science
2. Chairmen, BoS under Faculty of Science
3. The Heads concerned / Co-ordinator, Centre for Integrated Science
4. All DRs Examination wing - with a request to forward to concerned sections
5. AR DoA/ Conference Sections
6. PS To VC/PVC;PA To Registrar/CE.

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

2023 REGULATIONS

5-Year Integrated M. Sc. in Physics/

5-Year Integrated M. Sc. in Chemistry/

5-Year Integrated M. Sc. in Mathematics/

5-Year Integrated M. Sc. in Statistics/

5-Year Integrated M. Sc. in Biological Sciences

(2023 Admission onwards)

CENTER FOR INTEGRATED STUDIES

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

CENTER FOR INTEGRATED STUDIES

5-Year Integrated M. Sc. in Physics/ 5-Year Integrated M. Sc. in Chemistry / 5-Year Integrated M. Sc. in Mathematics/ 5-Year Integrated M. Sc. in Statistics/ 5-Year Integrated M. Sc. in Biological Sciences

Regulations, August 2023

(2023 Admission onwards)

PREAMPLE

This Regulations shall be called 'Regulations for 5-Year Integrated M. Sc. in Physics/ 5-Year Integrated M. Sc. in Chemistry/ 5-Year Integrated M. Sc. in Mathematics/ 5-Year Integrated M. Sc. in Statistics/ 5-Year Integrated M. Sc. in Biological Sciences.

1 Scope

1.1 These regulations shall apply to 5-Year Integrated M. Sc. in Biological Sciences/ 5-Year Integrated M.Sc. in Chemistry/ 5-Year Integrated M.Sc. in Mathematics/ 5-Year Integrated M.Sc. in Physics/ 5-Year Integrated M.Sc. in Statistics coordinated by Centre for Integrated Studies (CIS) along with the departments under Faculty of Science of Cochin University of Science and Technology with effect from 2023 admissions.

1.2 The provisions herein supersede all other regulations with respect to 5-Year Integrated M.Sc programme conducted by Centre for Integrated Studies (CIS).

2 Definitions

2.1 **Core course** means a course that the student admitted to a particular programme must successfully complete in order to receive the Degree and which can not be substituted by any other course.

2.2 **Departmental Core Course** means a core course offered by the department which conduct the 5-year integrated programme.

2.3 **Interdepartmental Core Course** means a core course offered by departments other than the department which is offering the 5-year integrated programme.

2.4 **Elective Course** means a course which can be substituted by equivalent course from the same or other departments.

2.5 **Departmental Elective** means an elective course offered by the department which conducts the 5 year integrated programme.

2.6 **Multidisciplinary course (MDC)** means an elective course offered by departments other than the department which is offering the 5 year integrated programme.

2.7 **Ability Enhancement Course (AEC)** means a course enabling students to acquire skills in reading, writing, comprehension, communication and developing social skills and responsibility.

2.8 **Skill Enhancement Course (SEC)** means a course which enables the students to develop and nuture theoretical and practical skills in a chosen area with a special focus to enhance employability.

2.9 **Value Added Course (VAC)** means a course empowering students to increase employability and to meet professional challenges.

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

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

2.12 **Department/School** means Department/School instituted in the University as per Statutes and Act.

2.13 **CIS** means The Centre for Integrated Studies, an interdepartmental centre to coordinate the 5 Year integrated Programmes. CIS shall manage common classrooms and laboratory facilities.

3 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. (Biological Sciences/ Chemistry/ Mathematics/ Physics/ Statistics) for imparting specialized education to the students on completion of their +2 level of education.

4 Courses coordinated by the Centre

The CIS coordinates 5-year integrated M. Sc (Biological Sciences, Chemistry, Mathematics, Physics and Statistics). The nomenclature of the course shall be 5-Year Integrated M.Sc. in Biological Sciences / 5-Year Integrated M.Sc. in Chemistry/ 5-Year Integrated M.Sc. in Mathematics/ 5-Year Integrated M.Sc. in Physics/ 5-Year Integrated M.Sc. in Statistics). These 5-Year Integrated M.Sc. programmes are a non-professional programme. The curriculum is common to all for the first three semesters. The students spend first three semesters of their program at the CIS.

5 Admission

The students are admitted to the departments which offer the programme of their choice. The intake for the 5-Year Integrated M. Sc (Biological Sciences/ Chemistry/ Mathematics/ Physics/ Statistics) is **75 (15 in each programme of study)**.

5.1 Eligibility and Entrance Examination

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

Programme of Study	Eligibility
5-Year Integrated M.Sc. in Physics	**60% marks or 6.5 CGPA** in the qualifying examination with Mathematics, Physics and Chemistry as subjects
5-Year Integrated M.Sc. in Chemistry	**60% marks or 6.5 CGPA** in the qualifying examination with Mathematics, Physics and Chemistry as subjects
5-Year Integrated M.Sc. in Mathematics	**60% marks or 6.5 CGPA** in the qualifying examination with Mathematics, Physics and Chemistry as subjects
5-Year Integrated M.Sc. in Statistics	**60% marks or 6.5 CGPA** in the qualifying examination with Mathematics, Physics and Chemistry as subjects
5-Year Integrated M.Sc. in Biological Sciences	**60% marks or 6.5 CGPA** in the qualifying examination with Biology, Physics and Chemistry as subjects

Students shall register their option for the preferred programme of study *i.e.*, 5-Year Integrated M.Sc. in Biological Sciences/ 5-Year Integrated M.Sc. in Chemistry/ 5-Year Integrated M.Sc. in Mathematics/ 5-Year Integrated M.Sc. in Physics/ 5-Year Integrated M.Sc. in Statistics at the time of submission of the application.

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

5.2 Entrance Examination

The admission to 5-Year Integrated M.Sc. in Biological Sciences/ 5-Year Integrated M.Sc. in Chemistry/ 5-Year Integrated M.Sc. in Mathematics/ 5-Year Integrated M.Sc. in Physics/ 5-Year Integrated M.Sc. in Statistics will be through the Common Admission Test examination (CAT) of CUSAT conducted by the Directorate of Admissions, CUSAT.

The students applying for 5-Year Integrated M.Sc. in Mathematics, 5-Year Integrated M.Sc. in Statistics, 5-Year Integrated M.Sc. in Chemistry and 5-Year Integrated M.Sc. in Physics shall write the entrance examination with Test code 101. The students applying for 5-Year Integrated M.Sc. in Biological Sciences shall write Test Code 104.

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

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

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

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

Rank list for 5-Year Integrated M.Sc. in Mathematics/5-Year Integrated M.Sc. in Statistics

(a) The rank list for 5-Year Integrated M.Sc. in Mathematics and 5-Year Integrated M.Sc. in Statistics shall be prepared from the test code 101 who opted for the 5-Year Integrated M.Sc. in Mathematics/5-Year Integrated M.Sc. in Statistics programmes. Total marks of Physics, Chemistry, and Mathematics will be ranked in the order. There shall be separate rank list for the Mathematics and Statistics programmes.

(b) For Tie Breaking in 5– year integrated M.Sc in Mathematics/ 5 – Year Integrated M.Sc in Statistics rank list, marks obtained for mathematics will be considered first with higher mark given preference.

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

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

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

Rank list for 5-Year Integrated M.Sc. in Physics

(a) The rank list for 5-Year Integrated M.Sc. in Physics shall be prepared from the test code 101 who opted for the 5-Year Integrated M.Sc. in Physics programme. Total marks of Physics, Chemistry, and Mathematics will be ranked in the order.

(b) For Tie Breaking in 5– year integrated MSc Physics rank list, marks obtained for Physics will be considered first with higher mark given preference.

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

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

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

Rank list for 5-Year Integrated M.Sc. in Chemistry

(a) The rank list for 5-Year Integrated M.Sc. in Chemistry shall be prepared from the test code 101 who opted for the 5-Year Integrated M.Sc. in Chemisty programme. Total marks of Physics, Chemistry, and Mathematics will be ranked in the order.

(b) For Tie Breaking in 5 – year integrated MSc Chemistry rank list, marks obtained for Chemistry will be considered first with higher mark given preference.

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

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

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

Rank list for 5-Year Integrated M.Sc. in Biological Sciences

(a) The rank list for 5-Year Integrated M.Sc. in Biological Sciences shall be prepared from the test code 104 who opted for the 5-Year Integrated M.Sc. in Biological Sciences programme. Total marks of Physics, Chemistry, and Biology will be ranked in the order.

(b) For Tie Breaking in 5– year integrated M.Sc Biological Sciences rank list, marks obtained for Biology will be considered first

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

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

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

6 Course Structure

- The duration of 5 – Year Integrated M. Sc. in Biological Sciences/ 5 – Year Integrated M. Sc. in Chemistry/ 5 – Year Integrated M. Sc. in Mathematics/ 5 – Year Integrated M. Sc. in Physics/ 5 – Year Integrated M. Sc. in Statistics is 10 semesters.

- The program follow OBE based CBCS system having core, elective and audit courses implemented in the University.

- The curriculum and syllabus framed by the board of studies in Chemical and Biological Sciences and the board of studies in Physical and Mathematical Sciences with inputs from the participating department councils approved by Academic Council is applicable to the 5– Year Integrated M.Sc. in Biological Sciences/ 5– Year Integrated M.Sc. in Chemistry/ 5– Year Integrated M.Sc. in Mathematics/ 5– Year Integrated M.Sc. in Physics/ 5– Year Integrated M.Sc. in Statistics.

- The department councils of the respective departments shall have the freedom to design and introduce new departmental and interdepartmental electives, to modify/redesign existing electives and to replace existing electives with new or modified/redesigned electives. Such changes shall be done with the approval of the academic committee and shall be ratified in the concerned board of studies, Faculty and Academic Council.
- Each semester shall have a minimum of 16 weeks and one credit shall be given for one hour lecture or 2 hours of lab/practical work per week.

6.1 Course/Credits

- The subjects for the 5-Year Integrated M.Sc. in Biological Sciences/ 5-Year Integrated M.Sc. in Chemistry/ 5-Year Integrated M.Sc. in Mathematics/ 5-Year Integrated M.Sc. in Physics/ 5-Year Integrated M.Sc. in Statistics are common in the first three semesters.
- The first two semesters will have interdepartmental core courses in English as first language (2 Credits/semester), and German/Malayalam/Hindi/French (2 credits/semester) as second language.
- The students will have the option of choosing their second language in their first semester.
- The students of the 5 -Year Integrated M.Sc. in Biological Sciences, Chemistry, Physics, Mathematics and Statistics will have the option of taking computer science or General Biology as interdepartmental course in the first three semesters.
- Students admitted to each branch of study will have a departmental core course for the first three semesters.
- In all semesters there shall be core courses (departmental/interdepartmental) and elective courses (departmental/interdepartmental/MOOC) as detailed in the curriculum and syllabus of the respective program.

The minimum number of credits required to successfully complete an individual Semester is as per the respective programme curriculum and syllabus. **The minimum**

credit required for successful completion of the 5 Year Integrated M. Sc. in toto is 215.

A student can take courses over and above those stipulated for a semester and can accumulate extra credits in a given semester, not exceeding the maximum of 24 credits per semester.

6.2 Audit Course

A student have the choice of 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 their department in writing. Courses thus audited should also be indicated in the course Registration forms along with other courses opted for that semester.

7 Course Registration and Attendance

The Integrated M. Sc. Course is conducted under OBE based CBCS. Students have to register for the courses of their choice within 10 days of commencement of a Semester. All students have to register for the core courses. They can choose the elective courses of their choice in consultation with their mentors. The student can drop/re-register any elective/audit course(s) within 15 working days after the commencement of the classes.

7.1 The students can choose MOOC courses from CUSAT, SWAYAM or other platforms as recommended by the Department Council and approved by the University from time to time. The course registration and provision for credit transfer for the credits acquired from the MOOC/SWAYAM platform shall be as per the general rules and regulations for MOOC courses issued by the university from time to time.

7.2 A student shall compulsorily register and complete at least one interdepartmental elective course from other departments/ Schools before registering for the final semester of the programme.

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

8 Evaluation

- Evaluation of 5- Year Integrated M.Sc in Biological Sciences/ 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), Open Ended Laboratory Courses, Mini project work and Final semester project work there will be only Continuous Assessment as per procedures laid down by the Department Council of the department offering the programme.
- For the Open Ended Laboratory Courses, Mini project work and Final semester project work at the end of the Semester, the Students will have to submit a report of the work done; they will present the results in a Seminar and should defend the work in a Viva- voce.

8.1 Continuous Assessment (CA)

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 relevant may be followed. The specific nature of the assignments/tests will be described by the faculty in the class and can vary from course to course. The student shall be given a minimum of two written tests per semester in each course. The faculty concerned can choose the mode of evaluation and compilation of final marks of CA ensuring all modules in the course syllabus covered in the assessment process with the approval of the department council of the participating department. The marks obtained in the continuous assessment shall be displayed on the notice board of CIS/Department and grievances if any may be addressed to the respective Head of the Department. The Department Council which offers the concerned programme shall finalize the marks of the continuous assessment of each course after addressing such grievances.

8.2 End-semester Examination (ESE)

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

There shall be only a single internal evaluation for the end semester examination. Immediately after the examination is over, course teachers shall complete the evaluations and the results shall be finalized within 10 working days after the last examination is over so as to enable students who have failed to appear for the makeup examination. The marks and grade in all the subjects obtained by the students has to be displayed in the notice board and the answer scripts can be made available to the students for scrutiny if necessary.

The final result in each course is calculated on the basis of continuous assessment and performance in the end-semester examination. For Semester End Examination, the students have to score a minimum of 45 % marks to get a pass. Also, the students should get a total of 50 % marks for each course (Sum of CA and ESE) to get a pass in the course.

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

The final marks and grades obtained by the students shall be published in the notice board. Those who could not obtain 45% marks in the End semester examination and 50% marks (Grade D) in total for a course will be declared as failed in that course. Those who fail in any core or elective course shall approach the Head of the Department if necessary for a makeup examination. Within one week of the display of the results in the notice board, the Head of the Department with the help of the course teacher shall conduct an additional semester end examination for these candidates. This makeup is only to enable the student to pass the examination so by completing the course successfully. If he/she completes the course successfully making use of this additional chance, he/she will be awarded only a D grade for that course. **The student may appear for the supplementary examination next year for improving the marks so obtained**.

Supplementary Examination: 5-Year Integrated M. Sc. in Biological Sciences/ 5-Year Integrated M. Sc. in Chemistry/ 5-Year Integrated M. Sc. in Mathematics/ 5-Year Integrated M. Sc. in Physics/ 5-Year Integrated M. Sc. in Statistics students, who after completion of the prescribed duration of the course, are left with backlogs, are eligible to appear for supplementary exams.

The maximum duration for completing the Integrated MSc degree programme will in any case be 9 years from the date of commencement of first semester (A student will have additional two years to complete the first level (*i.e.*, semester 1 – semester 6) and additional two years for completing the second level (*i.e..*, Semester 7 – Semester 10). Total additional years that can be availed is 4.

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

8.3 Grade Card

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

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

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

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

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

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

Range of Marks*	**Grades**	**Grade Points (G_i)**
90 and above	S - Outstanding	10
80 - 90*	A - Excellent	9
70 - 80*	B - Very Good	8
60 - 70*	C - Good	7
50 - 60*	D - Satisfactory	6
Below 50%	F - Failed	0

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

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

(i) The SGPA is the ratio of 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.*,

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

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

$$CGPA = \frac{\sum(C_i \times S_i)}{\sum C_i}$$

where S_i is the SGPA of the ith semester and C_i is the total number of credits in that semester.

Classification for the Degree will be given as follows:

Classification for the Degree	**CGPA**
First Class with distinction	8 and above
First Class	6.5 - 8*
Second Class	6 - 6.5*

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

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

9 Backlogs

No student of the 5-Year Integrated M.Sc. in Biological Sciences/ 5-Year Integrated M.Sc. in Chemistry/ 5-Year Integrated M.Sc. in Mathematics/ 5-Year Integrated M.Sc. in Physics/ 5-Year Integrated M.Sc. in Statistics shall be allowed to move to 3rd , 5th or 7th semester, if he/she does not satisfy the following conditions.

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

10 Readmission

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

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

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

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

11 Exit Option

The 5-Year Integrated M. Sc. in Biological Sciences/ 5-Year Integrated M. Sc. in Chemistry/ 5-Year Integrated M. Sc. in Mathematics/ 5-Year Integrated M. Sc. in Physics/ 5-Year Integrated M. Sc. in Statistics is a full time regular course. Option of Exit with a Bachelor's degree/Bachelors Degree with Honours/Bachelors degree with Honours (Research) is introduced for desiring students. The distinguishing features of the exit option are:

11.1 Exit with B.Sc. Degree

(a) The Exit Option with BSc Degree will be available at the end of three years in the case of the 5-Year Integrated M.Sc. (Biological Sciences/ Chemistry/ Mathematics/ Physics/ Statistics) students.

(b) Students who seek to opt out after 3 years (six semesters) should have passed all the courses of the preceding six semesters. For exercising the Exit Option, the students should have secured a minimum of 135 Credits in toto for semesters 1-6.

(c) Students who exercise 'Exit option' at the end of three years of the 5-Year Integrated M.Sc. in Biological Sciences/ 5-Year Integrated M.Sc. in Chemistry/ 5-Year Integrated M.Sc. in Mathematics/ 5-Year Integrated M.Sc. in Physics/ 5-Year Integrated

M.Sc. in Statistics will be given B.Sc. Degree Certificates. B.Sc. Degree in Chemistry or B.Sc. Degree in Mathematics or B.Sc. Degree in Physics, or the B.Sc. Degree in Statistics or B.Sc. Degree in Biological Sciences on the basis of the subject to which they are admitted.

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

11.2 Exit with B.Sc. Honours Degree

(a) The Exit Option with BSc Honours Degree will be available at the end of Four years in the case of the 5-Year Integrated M.Sc. (Biological Sciences/ Chemistry/ Mathematics/ Physics/ Statistics) students.

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

(c) Students who exercise 'Exit option' at the end of four years of the 5-Year Integrated M.Sc. in Biological Sciences/ 5-Year Integrated M.Sc. in Chemistry/ 5-Year Integrated M.Sc. in Mathematics/ 5-Year Integrated M. Sc. in Physics/ 5-Year Integrated M.Sc. in Statistics will be given B.Sc. Degree Honours Certificates. B.Sc. Degree Honours in Chemistry or B.Sc. Degree Honours in Mathematics or B.Sc. Degree Honours in Physics, or the B.Sc. Degree Honours in Statistics or B.Sc. Degree Honours in Biological Sciences on the basis of the subject to which they are admitted.

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

11.3 Exit with B.Sc. Honours (Research) Degree

(a) The Exit Option with B.Sc. Honours Degree will be available at the end of Four years in the case of the 5-Year Integrated M.Sc. (Biological Sciences/ Chemistry/

Mathematics/ Physics/ Statistics) students. The student may opt for BSc Honors with research at the end of seventh semester. The eligibility for a student to pursue BSc Honors with research shall be CGPA 8.0 up to sixth semester. The final selection of students shall be based on the criteria fixed by the respective Department Council.

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

(c) Students who exercise 'Exit option' at the end of four years of the 5-Year Integrated M.Sc. in Biological Sciences/ 5-Year Integrated M.Sc. in Chemistry/ 5-Year Integrated M.Sc. in Mathematics/ 5-Year Integrated M.Sc. in Physics/ 5-Year Integrated M.Sc. in Statistics will be given B.Sc. Degree Honours (Research) Certificates. B.Sc. Degree Honours (Research) in Chemistry or B.Sc. Degree Honours (Research) in Mathematics or B.Sc. Degree Honours (Research) in Physics, or the B.Sc. Degree Honours (Research) in Statistics or B.Sc. Degree Honours (Research) in Biological Sciences on the basis of the subject to which they are admitted.

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

12 Merger with the 2 Year M.Sc.

In the Fourth Year, students of the 5-Year Integrated M.Sc. (Chemistry/ Mathematics/ Physics/ Statistics) may be integrated with the students admitted for the 2 Year M. Sc. programme offered by the respective Departments to which they are admitted. **After merger *i.e.*, from 7th semester, any provision under this regulation inconsistent with the PG regulations in force for M.Sc. Chemistry/Mathematics/Physics/Statistics) shall not be applicable and the respective provision under PG regulation shall prevail.** The

5-Year Integrated M.Sc. (Biological Sciences) shall be conducted separately by the Department of Biotechnology as there is no regular 2 year M.Sc. programme in Biological Sciences.

13 Mentoring, Tutorial and Remedial classes

A system of mentoring by a teacher for a group of 15 students in the first three semesters will be coordinated by CIS. Mentor shall conduct orientation sessions to plan studies, utilize library and other common university and departmental resources. Mentor shall monitor academic progress of their mentee and identify weak learners in advance and arrange for remedial sessions in association with CIS/Equal opportunity cell/Department as the case may be. Special talents of their mentee may be identified and give guidance to nurture them. From 4th semester onwards a mentor will be assigned to a group of 5 students by the respective departments. Mentor in association with CIS/Department shall coordinate internships/summer research programs/vacation activity during vacation months.

14 Transitory Provisions

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

15 Repeal

The regulations now in force, in so far as they are applicable to 5-Year Integrated M.Sc. (Biological Sciences/ Chemistry/ Mathematics/ Physics/ Statistics) conducted by Centre for Integrated Studies (CIS) and to the extent they are inconsistent with the existing regulations, and the regulations relating to the CBCS System in their application to any programme offered in a University Department, the latter shall prevail.

SEMESTER I

Course Code	Name	C/E	L-T-P	Marks Distribution			Credit
				Continuous evaluation	End semester	Total	
ENG 10101	English – I	C (AEC1)	2-0-0	50	50	100	2
MAL 10101	Malayalam – I*	C (AEC2)	2-0-0	50	50	100	2
HIN 10101	Hindi – I*	C (AEC2)	2-0-0	50	50	100	2
GER 10101	German- I*	C (AEC2)	2-0-0	50	50	100	2
BIO 10101	Fundamentals of Life	C	3-1-0	50	50	100	3
BIO 10102	Fundamentals of Life Lab	C	0-0-4	100	-	100	2
CHE 10101	General Chemistry I	IDC	3-1-0	50	50	100	3
CHE 10102	Quantitative Analysis Lab	IDC	0-0-4	100	-	100	2
PHY 10101	General Physics I	IDC	3-1-0	50	50	100	3
PHY 10102	Physics Lab I (Mechanics)	IDC	0-0-4	100	-	100	2
BIO 10103	General Biology	IDE	3-1-0	50	50	100	3
CSP 10101	Computer Science 1	IDE	3-1-0	50	50	100	3
MAT 10103	Mathematical methods 1	IDE	3-1-0	50	50	100	3
STAT 10101	Statistical methods for data	IDE	3-1-0	50	50	100	3
	Total			**550**	**350**	**900**	**22**

AEC-Ability enhancement course; MDC- Multidisciplinary Course; VAC- Value Added course; SEC- Skill Enhancement course, IDE- Interdepartmental elective

*Either Malayalam- I, Hindi- I or German- I is to be opted.
The students must opt minimum one IDE
C- Core Course, IDC - Interdepartmental Core Course, IDE - Interdepartmental Elective Course,
DE- Departmental Elective Course
L- Lecture, T - Tutorial, P - Practical

SEMESTER II

Course Code	Name	C/E	L-T-P	Marks Distribution			Credit
				Continuous evaluation	End semester	Total	
ENG 10201	English – II	C (AEC3)	2-0-0	50	50	100	2
MAL 10201	Malayalam – II*	C (AEC4)	2-0-0	50	50	100	2
HIN 10201	Hindi – II*	C (AEC4)	2-0-0	50	50	100	2
GER 10201	German- II*	C (AEC4)	2-0-0	50	50	100	2
BIO 10201	Biochemistry	C	3-1-0	50	50	100	3
BIO 10202	Biochemistry Lab	C	0-0-4	100	-	100	2
CHE 10201	General Chemistry II	IDC	3-1-0	50	50	100	3
CHE 10202	Inorganic Qualitative Analysis Lab	IDC	0-0-4	100	-	100	2
PHY 10201	General Physics II	IDC	3-1-0	50	50	100	3
PHY 10202	Physics Lab II (Waves and Optics)	IDC	0-0-4	100	-	100	2
BIO 10203	Biophysical Chemistry	IDE	3-1-0	50	50	100	3
MAT 10203	Mathematical Methods II	IDE	3-1-0	50	50	100	3
CSP 10201	Computer Science II	IDE	3-1-0	50	50	100	3
STA10201	Probability and Distributions	IDE	3-1-0	50	50	100	3
	Total			**550**	**350**	**900**	**22**

AEC-Ability enhancement course; MDC- Multidisciplinary Course; VAC- Value Added course; SEC- Skill Enhancement course, IDE- Interdepartmental elective

*Either Malayalam- II, Hindi- II or German- II is to be opted.
The students must opt minimum one IDE
C- Core Course, IDC - Interdepartmental Core Course, IDE - Interdepartmental Elective Course,
DE- Departmental Elective Course
L- Lecture, T - Tutorial, P - Practical

SEMESTER III

Course Code	Name	C/E	L-T-P	Marks Distribution Continuous evaluation	End semester	Total	Credit
BIO 10301	Genetics and Molecular Biology	C	3-1-0	50	50	100	3
BIO 10302	Genetics and Molecular Biology Lab	C	0-0-4	100	-	100	2
CHE 10301	General Chemistry III	IDC	3-1-0	50	50	100	3
CHE 10302	Organic Qualitative Analysis Lab	IDC	0-0-4	100	-	100	2
PHY10301	General Physics III	IDC	3-1-0	50	50	100	3
PHY 10302	Physics Lab III (Electricity and Magnetism)	IDC	0-0-4	100	-	100	2
YYY 10301	Environmental Science	IDC (VAC1)	4-1-0	50	50	100	4
BIO 10303	Human Disease and Healthcare Management	IDE	3-1-0	50	50	100	3
MAT 10303	Matrix Theory and Graph Theory	IDE	3-1-0	50	50	100	3
CSP 10301	Computer Science III	IDE	3-1-0	50	50	100	3
STA10301	Statistical Inference	IDE	3-1-0	50	50	100	3
	Total			**550**	**250**	**800**	**22**

AEC-Ability enhancement course; MDC- Multidisciplinary Course; VAC- Value Added course; SEC- Skill Enhancement course, IDE- Interdepartmental elective

The students must opt minimum one IDE
C- Core Course, IDC - Interdepartmental Core Course, IDE - Interdepartmental Elective Course,
DE- Departmental Elective Course
L- Lecture, T - Tutorial, P - Practical

SEMESTER IV

Course Code	Name	C/E	L-T-P	Marks Distribution			
				Continuous evaluation	End semester	Total	Credit
BIO 10401	Introduction to Biotechnology	C	4-1-0	50	50	100	4
BIO 10402	Basic principles of Metabolism	C	4-0-0	50	50	100	4
BIO 10403	Essential Cell Biology	C	4-0-0	50	50	100	4
BIO 10404	Animal forms and functions	C	4-1-0	50	50	100	4
BIO 10405	Cell Biology & Biochemistry Lab	C	0-0-8	100	-	100	4
Sxxxx	Skill enhancement course#	E (SEC1)	0-0-3	100	-	100	3
	Total			**400**	**200**	**600**	**23**

AEC-Ability enhancement course; MDC- Multidisciplinary Course; VAC- Value Added course; SEC- Skill Enhancement course.

Student shall select the course from a bouquet of courses offered by various departments

SEMESTER V

Course Code	Name	C/E	L-T-P	Marks Distribution			Credit
				Continuous evaluation	End semester	Total	
BIO 10501	Plant Diversity I (Algae/Fungi/Bryophytes/Pteridophytes/Paleobotany)	C	4-1-0	50	50	100	4
BIO 10502	Non-chordates	C	4-1-0	50	50	100	4
BIO 10503	Plant Diversity II (Gymnosperms & Angiosperms)	C	4-1-0	50	50	100	4
BIO 10504	Elective	E	4-1-0	50	50	100	4
BIO 10505	Plant Lab and Animal Lab- I	C	0-0-8	100	-	100	4
Sxxxx	Skill enhancement course#	E (SEC2)	0-0-3	100	-	100	3
	Total			**400**	**200**	**600**	**23**

AEC-Ability enhancement course; MDC- Multidisciplinary Course; VAC- Value Added course; SEC- Skill Enhancement course.

Student shall select the course from a bouquet of courses offered by various departments

SEMESTER VI

Course Code	Name	C/E	L-T-P	Marks Distribution			Credit
				Continuous evaluation	End semester	Total	
BIO 10601	Evolution and developmental Biology	C	4-1-0	50	50	100	4
BIO 10602	Parasitology and Immunology	C	4-1-0	50	50	100	4
BIO 10603	Chordates	C	4-1-0	50	50	100	4
BIO 10604	Parasitology & Immunology Lab	C	0-0-8	100	-	100	4
BIO 10605	Elective	E	4-1-0	50	50	100	4
Sxxxx	Skill enhancement course#	E (SEC3)	0-0-3	100	-	100	3
	Total			**400**	**200**	**600**	**23**

Student shall select the course from a bouquet of courses offered by various departments

Exit with BSc Biological Sciences – Total Credit required - 135

SEMESTER VII

Course Code	Name	C/E	L-T-P	Marks Distribution			Credit
				Continuous evaluation	End semester	Total	
BIO 10701	Cellular metabolism	C	4-1-0	50	50	100	4
BIO 10702	Cell Biology	C	4-1-0	50	50	100	4
BIO 10703	Advanced Microbiology	C	4-1-0	50	50	100	4
BIO 10704	Molecular Biology	C	4-1-0	50	50	100	4
BIO 10705	Advanced Biology Lab- I	C	0-0-4	100	-	100	2
BIO 10706	Professional and career aspects in Biotechnology	A	2-0-0	-	-	-	0
BIO10707	Elective	E	3-1-0	50	50	100	4
	Total			**350**	**250**	**600**	**22**

BSc Honours with Research

Course Code	Name	C/E	L-T-P	Marks Distribution			Credit
				Continuous evaluation	End semester	Total	
BIO 10801	Elective	E	4-1-0	50	50	100	4
BIO 10802	Project with report	C	-	-	300	300	16
	Total			**50**	**350**	**400**	**20**

Exit with B.Sc Biological Sciences Honours (Research)- Total Credit required- 177

SEMESTER VIII

Course Code	Name	C/E	L-T-P	Marks Distribution			Credit
				Continuous evaluation	End semester	Total	
BIO 10801	Enzymology	C	4-1-0	50	50	100	4
BIO 10802	Plant physiology and Biochemistry	C	4-1-0	50	50	100	4
BIO 10803	Human Physiology and Endocrinology	C	4-1-0	50	50	100	4
BIO 10804	Elective	E	4-1-0	50	50	100	4
BIO 10805	Advanced Biology Lab- II	C	0-0-8	100	-	100	4
	Total			**300**	**200**	**500**	**20**

Exit with B.Sc Biological Sciences Honours – Total Credit required - 177

SEMESTER IX

Course Code	Name	C/E	L-T-P	Marks Distribution			
				Continuous evaluation	End semester	Total	Credit
BIO 10901	Immunology	C	4-1-0	50	50	100	4
BIO 10902	Genetic Engineering	C	4-1-0	50	50	100	4
BIO 10903	Research methodology	C	4-1-0	50	50	100	4
BIO 10904	Bioethics, Biosafety and IPR	C	4-1-0	50	50	100	4
BIO 10905	Elective	E	4-1-0	50	50	100	4
BIO 10906	Advanced Biology Lab- III	C	0-0-4	100	-	100	2
	Total			**350**	**250**	**600**	**22**

SEMESTER X

Course Code	Name	C/E	L-T-P	Marks Distribution			
				Continuous evaluation	End semester	Total	Credit
BIO 11001	Project presentation and Viva voce	C	-	-	300	300	16
	Total				**300**	**300**	**16**

Total Credits Required for Integrated M.Sc Biological Sciences- 215

Semester 1

BIO10101. FUNDAMENTALS OF LIFE

Course description: The course covers the studies of living creatures, from the tiny and simple through to the complexities of plants and animals, ending with a basic understanding of ecology and the study of population dynamism. Different scopes of biology will also be conveyed to the students.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the biological processes common to life	Understand
C.O. 2: Compare fundamental differences in the forms and how they may differ	Analyze
C.O. 3: Comprehend and explain how present-day organisms may have arisen	Understand
C.O. 4: Interpret how different life forms, including humans, interact with each other and with the physical, chemical and biological world around them.	Analyze
C.O. 5: Use the knowledge gained through scopes of biology for higher studies and furthering careering in biology.	Apply

MAPPING of CO's and PO's

	Program 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

Introduction to cell: Cell theory, Cell and its components: nucleus, mitochondria, chloroplast, Golgi apparatus, ribosomes, vacuoles; types of cells, the concept of tissues

MODULE II

Biomolecules of life: Water as a biological solvent, carbohydrate, nucleic acid, amino acids, proteins, lipids, enzymes, vitamins, and minerals.

MODULE III

Biodiversity: concept, values and types of biodiversity. Analysing and documenting biodiversity. Maintenance of ecological diversity, Biodiversity hotspots in India.

MODULE IV

Ecology and Conservation: Concepts and elements of Biotic and Abiotic environment; Interaction between biotic and abiotic environment; Ecosystem- concept and components, Community-structure and dynamics; Biome- grassland, tundra, forest, deserts, salt & freshwater ecosystem; Biodiversity and Conservation; Impact of climate change on biodiversity.

MODULE V

Principles of Developmental Biology & Evolution: Basic concepts in developmental biology regarding plants and animals, and their biological significance Introduction to evolution: History, Types, Theories, and evidence of Evolution.

BIO10102. FUNDAMENTALS OF LIFE LAB

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the principle of various microscopic techniques	Understand
C.O. 2: Show the skills to independently operate microscopes for analysing and recording image data	Apply
C.O. 3: Differentiate various unicellular and multicellular life forms and identify them based on their morphology by microscopy	Analyze
C.O. 4: Identify various types of evolution with the help of pictures	Remember
C.O. 5: Evaluate the stages of development of volvox from unicellular to multicellular forms	Evaluate

MAPPING of CO's and PO's

	Program 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

1. Familiarizing with microscopes and their application.
2. Microscopic examination and identification of unicellular and multicellular life forms: Monerans: Euglena, Paramecium, Amoebae, Chlamydomonas, Chlorella, Diatoms.
3. Microscopic observation of bacteria and fungi

4. Volvox as a model of evolution- (Cellular level- single cell to the multicellular organization)

REFERENCES

1. Reece, J. B., & Campbell, N. A. (2011). Campbell Biology. Boston, Benjamin Cummings / Pearson.
2. Manuel C Molles, Ecology: Concepts and Applications McGraw Hill 7th Edition 2014
3. Douglas J Futuyma, Evolution Oxford University Press 3rd Edition 2013
4. Barton et al., Evolution Cold Spring Harbor Laboratory Press 1st Edition 2007
5. Stephen C. Stearns and Rolf F. Hoekstra, Evolution: An Introduction Oxford University Press 1st Edition 2000
6. Nicholas J. Gotelli, A primer of Ecology Oxford University Press, 4th Edition 20086. Begon et al., Ecology: From Individuals to Ecosystem Wiley-Blackwell, 4th Edition 2005
7. Instant notes on ecology by A. Mackenzie, A.S. Ball, S.R. Virdee, 2nd edition- 2020

BIO10103. GENERAL BIOLOGY

MODULE I

Introduction: History of Biology, Chemical basis of life; diversity of life forms; Characteristic features of living organisms, Hierarchical levels of organization in living organisms (molecules, organelles, cells, tissues, organs, organisms, populations, communities, ecosystems)

Module II

Various forms of life prokaryotes and eukaryotes, Introduction to kingdom classification, Modes of nutrition (Autotrophs, heterotrophs), Ingestion and absorption; concepts of basic metabolism; concepts of growth, Photosynthesis, reproduction, regulation, death, cellular basis of inheritance and their pattern.

MODULE III

Scope of Biology: Branches, applications, and scope of biology. Integration of Biology with various fields for human welfare. Novel concepts and recent revolutionary discoveries in Biology. Contributions of living organisms to human health and sustenance. Biological systems or processes inspired by technological inventions or innovations and harnessing these for sustainable development.

REFERENCES

1. Reece, J. B., & Campbell, N. A. (2011). Campbell Biology. Boston, Benjamin Cummings Pearson
2. Manuel C Molles, Ecology: Concepts and Applications McGraw Hill 7th Edition 2014
3. Douglas J Futuyma, Evolution Oxford University Press 3rd Edition 2013 4. Barton et al., Evolution Cold Spring Harbor Laboratory Press 1st Edition 2007
4. Stephen C. Stearns and Rolf F. Hoekstra, Evolution: An Introduction Oxford University Press 1st Edition 2000
5. Nicholas J. Gotelli, A primer of Ecology Oxford University Press, 4th Edition 20086. Begon et al., Ecology: From Individuals to Ecosystem Wiley-Blackwell, 4th Edition 2005

Semester II

SEMESTER II

BIO 10201- BIOCHEMISTRY

Course description: The program is designed to enable a student to acquire sound knowledge of biochemistry and its practical applicability. The course will encourage the students to join the industry or to prepare them for higher studies including research. The syllabus is based on a basic and applied approach to ensure that students develop problem-solving skills, laboratory skills, chemistry communication skills, team skills as well as ethics.

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the significance of biomolecules	Understand
C.O. 2: Differentiate the biomolecules (proteins, lipids, nucleic acids, and carbohydrates) based on their structural basis	Analyze
C.O. 3: Quantify various biomolecules.	Analyze
C.O. 4: Employ chromatographic techniques to separate various biomolecules.	Apply
C.O. 5: Apply proper procedures and regulations in handling and disposal of chemicals.	Apply

MAPPING of CO's and PO's

	Program 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

A brief history of biochemistry, Basic chemistry- Elements, Functional groups, pH, Mole concept, Bonding and chirality, non-covalent interactions, Water, interactions in aqueous systems, Molarity, normality, Ionization state of biomolecules, Laws of thermodynamics, Gibbs free energy, and maintenance of equilibrium.

MODULE II

Carbohydrates: Structure, chemical & biological properties and functions. Monosaccharides- Ribose, Glucose and fructose. Oligosaccharides -Sucrose, maltose, lactose, Polysaccharides- Glycogen, cellulose and starch. Glycoproteins, proteoglycans and glycolipids. Heteropolysaccharides, Carbohydrates as informational molecules- the sugar code.

MODULE III

Nucleic Acids: Nucleotides, Nucleic Acid composition, a historical perspective leading up to the proposition of DNA double-helical structure; the difference in RNA and DNA structure and their importance in the evolution of DNA as the genetic material. Lipids & Fats: Storage lipids, Structural lipids in membranes, Lipoproteins. Lipids as signals, cofactors and pigment, biological functions of lipids. Vitamins and Minerals: General accounts and biological functions.

MODULE IV

Proteins: structural and functional group properties; pH and properties of amino acids, Peptides and covalent structure of proteins; peptide bond, polypeptide, protein structure-secondary, tertiary and quaternary, protein structure & function, Enzymes as Biological Catalysts: General principles of enzyme catalysis, Activation energy and stereospecificity, classification of enzymes; Types of enzymes and their specific functions. Enzyme characterization and Michaelis-Menten kinetics, Regulation and Inhibition of enzyme.

MODULE V

Methods in Biophysical and Biochemical Analysis: Buffers, pH meter, Calorimetry, Spectrophotometry, Centrifugation techniques, Mass spectrometry, Chromatographic techniques, Electrophoretic Techniques.

BIO 10202- BIOCHEMISTRY LAB

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the concept of Molarity, Normality, pH etc	Understand
C.O. 2: Apply standard procedures to prepare different Molar solutions and buffers of different ph.	Apply/Create
C.O. 3: Calculate the quantity of biomolecules in solutions by spectrometry	Analyze
C.O. 4: Separate biomolecules based on chromatographic techniques	Apply
C.O. 5: Differentiate various biomolecules in solutions based on colorimetric techniques	Analyze

MAPPING of CO's and PO's

	Program 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	x			
C.O.3					x	
C.O.4		x				
C.O.5					x	

1. Preparation of Normal and Molar solutions
2. Preparation of Buffers (Acidic, Neutral and Alkaline Buffers)
3. Verification of Beer Lambert's law
4. Estimation of biomolecules (glucose, protein, lipids and nucleic acid).
5. Separation of biomolecules using paper and TLC
6. Electrophoretic Techniques

REFERENCES

1. Rodney F Boyer, Concepts in Biochemistry. John Wiley & Sons; 3rd Ed (2 December 2005).
2. Thomas Millar, Biochemistry Explained: A Practical Guide to Learning Biochemistry CRC Press; 1 edition (30 May 2002)
3. Lubert Stryer et al., Biochemistry.W. H. Freeman; 6th Edition (14 July 2006)
4. David L Nelson, and Michael M Cox et al., Lehninger principles of biochemistry WH Freeman; 7th ed.2017 edition (1 January 2017)
5. Lehninger. Principles of Biochemistry, Macmillan, U.K.
6. Geoffrey Zubay. Biochemistry. Macmillan Publishing company, New York
7. Sadasivam and Manickam. Biochemical Methods. New Age International Publishers. NewDelhi.
8. David T. Plummer, An Introduction to Practical Biochemistry. Tata McGraw Hill.
9. Nelson, D. L., Lehninger, A. L., & Cox, M. M. (2008). Lehninger principles of biochemistry. Macmillan
10. Tymoczko, J. L., Berg, J. M., &Stryer, L. (2011). Biochemistry: a short course. Macmillan.
11. Voet, D., & Voet, J. G. (2016). Fundamentals of Biochemistry. 5th Edition. Wiley & Sons.

BIO 10203- BIOPHYSICAL CHEMISTRY

Course Description: This course aims to provide an overview of some of the fundamentals of biophysics and biochemistry. The course will discuss advanced topics with an emphasis on structure, function relationships and techniques for probing structure and dynamics of biological system.

Learning Outcome:

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

C.O. 1: Describe the basic units in biological science	Understand
C.O. 2: Differentiate the different types of microscopes and their working principles	Analyze
C.O. 3: Elucidate the mechanisms of various separation techniques in molecular biology studies	Apply
C.O. 4: Elucidate the mechanisms of various separation techniques in spectroscopy and their applications	Apply

MAPPING of CO's and PO's

	Program 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

Introduction to measurements, SI units-standard units for measurement, Basic units, Derived units-volume; Mole concept; Hydrogen ion concentration. -pH. Determination of pH. Dissociation of weak acids (pKa), Buffers of blood plasma, red blood cells and tissue fluids.; Properties of covalent molecules- bond length, energy and bond angle. Hydrogen bond, inter-and intra-bio-molecular interactions.

MODULE II

Basics of microscopy: principle, working, types (light, electron microscopy) and application of microscopy in life science research; Separation techniques: Chromatography- basic principles, types and application; Centrifuge- Basic principle, types and applications, Electrophoresis- Basic principle, types and applications; Biopolymers-Classification. polymerization process.

MODULE III

Spectroscopy: Basic principles, Beer-Lamberts law, types and applications, X-ray crystallography and NMR spectroscopy, Radioisotopes- applications in life science

REFERENCE

1. Rodney F Boyer, Concepts in Biochemistry. John Wiley & Sons; 3rd Ed (2 December 2005)
2. Single Molecule Biology. (2009). Netherlands: Elsevier Science
3. McMurry, J. (2013). Fundamentals of General, Organic, and Biological Chemistry. United Kingdom: Pearson.

4. Springer Handbook of Microscopy. (2019). Germany: Springer International Publishing.
5. Roberson, R. W., Chandler, D. E. (2009). Bioimaging: current concepts in light and electron microscopy. United Kingdom: Jones and Bartlett Publishers.
6. Gel Electrophoresis. (1964). United States: Academy.
7. Pavia, D. L., Vyvyan, J. A., Lampman, G. M., Kriz, G. S. (2014). Introduction to Spectroscopy. United States: Cengage Learning.

Semester III

SEMESTER III

BIO 10301- GENETICS AND MOLECULAR BIOLOGY

Course Description: This course aims to provide an overview of genetics starting from the work of Mendel to the current understanding of various phenomena like recombination, transposition, sex determination and mutations. The course will help in building sound fundamental knowledge of the principles of genetics, to be used as a stepping stone for higher studies and research in this field. The course also aims to provide students with an introduction of the underlying molecular mechanisms of various biological processes in cells and organisms. The study primarily involves learning about the structure and synthesis of deoxyribo and ribo-nucleic acids, the formation of proteins, and the regulation of gene expression. The course aims to develop a basic understanding of molecular biology techniques and their applications.

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the basic principles of inheritance with examples	Understand
C.O. 2: Differentiate the basic structures of DNA and RNA	Analyze
C.O. 3: Explain the mechanisms of mutations, the causative agents and the harmful impact of various chemicals and drugs being used in day-to-day life.	Understand
C.O. 4: Predict the inheritance pattern of heredity based on classical genetics	Apply
C.O. 5: Discuss the DNA replication machinery in prokaryotes and eukaryotes.	Understand
C.O.6: Explain the mechanism of the flow of genetic information in prokaryotes and eukaryotes	Understand
C.O.7: Explain genetics of inheritance and apply	Apply
C.O.8: Calculate the concentration of DNA and RNA by spectrophotometric methods.	Analyze

MAPPING of CO's and PO's

	Program 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

Mendelian Genetics- Mendelian principles, the concept of traits & alleles, monohybrid and dihybrid crosses, back cross and test cross and Mendel's success, Modified Mendelian ratios; Incomplete dominance, Recessive and Dominant epistasis, Complementary genes, Duplicate gene, Duplicate dominant genes and Inhibitory factor. Multiple Alleles-General accounts. ABO blood group in man. Rh factor. Quantitative characters- quantitative inheritance, polygenic inheritance, cytoplasmic inheritance.

MODULE II

Linkage and crossing over- Linkage and its importance, linkage and independent assortment. Complete and incomplete linkage. Crossing over – a general account, two-point and three-point test crosses. Determination of gene sequence. Interference and coincidence. Mapping of chromosomes (recombination mapping) and complementation analysis. Conjugation, transduction and transformation. Sex determination- Sex chromosomes, the chromosomal basis of sex determination in Drosophila and humans. Pedigree analysis.

MODULE III

Introduction: history, development and scope of molecular biology. DNA as the genetic material, Griffith's experiment, Avery, Mac Leod and Mc Carty, experiment, Hershey & Chase's experiment. Structure of nucleic acids - Watson - Crick model of DNA, DNA replication in prokaryotes and eukaryotes. Semi-conservative method. Replication machinery and mechanism, enzymes involved in DNA replication. Arrangement of DNA in a chromosome-Nucleosome structure. Modification and repair of DNA. Different types of DNA and RNA.

MODULE IV

Gene Expression: One gene-one enzyme hypothesis, one gene-one polypeptide hypothesis, central dogma hypothesis, colinearity of genes and gene products. RNA: structure & types, Genetic code - features and wobble hypothesis. Contributions of Nirenberg and his associates, Khorana and his associates. Transcription of RNAs and post-transcriptional modifications & reverse transcription and PCR. Translation and post-translational modification of proteins

MODULE V

Gene regulation in prokaryotes; operon concept - Lac operon and Trp operon. Regulation of eukaryotic gene expression. Level of control of gene expression, transcriptional factors, regulation of RNA processing, mRNA translation, mRNA degradation & protein degradation control, epigenetics.

BIO 10302- GENETICS AND MOLECULAR BIOLOGY LAB

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the basic principles of inheritance with examples	Understand
C.O. 2: Predict the inheritance pattern of heredity based on classical genetics	Analyze
C.O. 3: Stain barr bodies from cheek cells and visualize to identify barr bodies	Apply and analyze
C.O. 4: Analyze chromosomes by karyotyping	Analyze
C.O. 5: Explain semiconservative replication of DNA using photographs	Understand
C.O.6: Explain the mechanism of flow of genetic information in prokaryotes and eukaryotes	Understand
C.O.7: Predict the GC content of DNA	Analyze
C.O.8: Calculate the concentration of DNA and RNA by spectrophotometric methods.	Analyze

MAPPING of CO's and PO's

	Program 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	

Genetics

1. Monohybrid cross and Dihybrid cross using Pea plant & Drosophila.
2. Gene interactions
    a. Recessive epistasis 9: 3: 4.
    b. Dominant epistasis 12: 3: I
    c. Complementary genes 9: 7
    d. Duplicate genes with cumulative effect 9: 6: 1
    e. Inhibitory genes 13: 3
    f. Duplicate dominant gene 15: 1
    g. Comb pattern in poultry 9:3: 3:1

3. Barr body staining from cheek cells
4. Preparation of human karyotype and study of chromosomal aberrations with respect to number, translocation, deletion, etc. from the pictures provided.
5. Pedigree analysis- Blood Groups, Free hanging earlobes, Widow's Peak, Rolling of the tongue, colour blindness.

Molecular Biology

1. Study of semiconservative replication of DNA through micrographs/schematic representations.
2. Practice problems in molecular biology based on Chargaff's rule, DNA structure and replication.
3. Model making using balls and sticks-Nucleic acids.
4. DNA isolation
5. PCR amplification of DNA (Demo)
6. Preparation of Nucleic Acid models
7. Electrophoretic separation of Nucleic Acid/Proteins

REFERENCES

1. Alberts, B., Johnson, A., Walter, P., Lewis, J., Raff, M., & Roberts, K. (2008). Molecular cell biology. New York: Garland Science.
2. Lodish, H., Berk, A., Darnell, J. E., Kaiser, C. A., Krieger, M., Scott, M. P. & Matsudaira, P. (2008). Molecular cell biology. Macmillan.
3. Lewin, B., Krebs, J. E., Goldstein, E. S., & Kilpatrick, S. T. (2014). Lewin's Genes XI. Jones & Bartlett Publishers.
4. Cooper, G. M., Hausman, R. E., &Hausman, R. E. (2000). The cell: a molecular approach (Vol. 2). Washington, DC: ASM press.
5. Hardin, J., Bertoni, G. P., & Kleinsmith, L. J. (2017). Becker's World of the Cell. Pearson Higher Ed.
6. Baker, T. A., Watson, J. D., & Bell, S. P. (2003). Molecular biology of the gene. Benjamin-Cummings Publishing Company.

BIO 10303- HUMAN DISEASES AND HEALTH CARE MANAGEMENT

Course Description: This course will introduce to the basic knowledge of various aspects of human diseases and healthcare industry. It also aims to understand various factors that contribute to the occurrence of diseases and how those diseases may be treated by clinical professionals.

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Demonstrate a basic understanding of the mechanism of diseases, diagnosis and the treatment	Understand
C.O. 2: Discuss common laboratory and diagnostic tests	Understand
C.O. 3: Discuss the various aspects of public health policy and health care management	Apply

MAPPING of CO's and PO's

Program 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					

MODULE I

Epidemiology and Infectious Diseases. Overview of epidemiology, epidemiology tools, history of diseases, quantifying disease in a population, comparing disease rate, outbreaks of disease, epidemiological aspects of infections and chronic diseases of national importance.

MODULE II

Basics of Pathophysiology. Introduction to the basics of pathophysiology, altered cellular and tissue biology, cellular adaptation, atrophy, hypertrophy, hyperplasia, dysplasia, metaplasia, cell injury, immunological & inflammatory injury, manifestations of cellular injury, cell death: apoptosis, necrosis, and autophagy.

MODULE III

Pathophysiology of Organ Dysfunction and Disorders. Diseases of the nervous system, Diseases of the endocrine system, Diseases of the cardiovascular system, Diseases of the reproductive system and sexually transmitted diseases.

MODULE IV

Genetic Disorders: General introduction to human genetics and various genetic disorders, autosomal and X-linked disorders, gene mutation and chromosomal abnormalities, inborn errors of metabolism, pedigree analysis, introduction to cytogenetics and its applications.

MODULE V

Public Health Policy and Health care Management: Overview of public health policy, an overview of WHO and global health policies, an overview of Indian public health policies, Health Care Management Overview of public health care management in India and other countries.

REFERENCES

1. Pathophysiology of Disease: An Introduction to Clinical Medicine 8E. (2018). United Kingdom: McGraw-Hill Education.
2. Marya, R. K. (2006). Pathophysiology. India: CBS Publishers & Distributors.
3. Wright, A., Hastie, N. (2007). Genes and Common Diseases: Genetics in Modern Medicine. United Kingdom: Cambridge University Press.
4. Thompson, E. A. (1986). Pedigree Analysis in Human Genetics. United Kingdom: Johns Hopkins University Press.
5. Pal, G. P. (2009). Medical Genetics. India: A.I.T.B.S. Publishers.
6. Agarwal, V. K. (2009). Genetics. India: S. Chand Limited.
7. Introduction to Health Care Management. (2016). United States: Jones & Bartlett Learning.

Semester IV

SEMESTER IV

BIO 10401- INTRODUCTION TO BIOTECHNOLOGY

Course Description: This course is designed to give students both theoretic background and a working knowledge of instrumentation and techniques employed in a biotechnology lab. Emphasis will be placed on the introduction of foreign DNA into bacterial cells as well as the analysis of nucleic acids and proteins.

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the different frontiers in Biotechnology	Understand
C.O. 2: Explain the mechanisms of molecular cloning	Understand
C.O. 3: Elucidate the mechanism of data mining and data processing	Apply
C.O. 4: Learn and apply the knowledge of IPR and patenting in Biotechnology	Understand

MAPPING of CO's and PO's

	Program 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

Major areas of Biotechnology, revolutionary discoveries and their applications: blue biotechnology (marine) White biotechnology (industry), yellow biotechnology (food production), grey biotechnology (bioremediation and environmental improvement), brown biotechnology (desert), gold biotechnology (bioinformatics, nanotechnology and computer science), violet biotechnology (legal, ethical and philosophical issues), dark biotechnology (bioweapons and warfare).

MODULE II

Molecular techniques in gene manipulation: Restriction enzymes, cloning vectors and expression vectors, steps involved in cloning, transformation techniques. Cloning and expression vectors. Restriction enzymes- nomenclature, types and mechanisms. Transformation techniques- gene gun, calcium chloride method and electroporation. Genomic and cDNA library construction and their applications

MODULE III

Genetically modified organisms: Applications and status, Production of genetically modified plants and animals with examples. Selection of transgenics using various techniques

MODULE IV

General bioinformatics: Different types of file formats, biological data, and databases- general classification. Text-based and sequence-based search engines, Sequence alignment techniques. Introduction to different operating systems.

MODULE V

Intellectual property rights: Introduction, commercialisation, patent laws, copyrights, royalty, plagiarisms, citations, acknowledgments. Geographical indications, protection of plant varieties.

REFERENCES

1. Basic Biotechnology. (2006). United Kingdom: Cambridge University Press.
2. Dubey, R. C. (1993). A Textbook of Biotechnology. India: S. Chand Limited.
3. Loroch, V., Renneberg, R. (2016). Biotechnology for Beginners. Germany: Elsevier Science.
4. Pazdernik, N., Clark, D. P. (2012). Molecular Biology. Netherlands: Elsevier Science.
5. Ploegh, H., Amon, A., Berk, A., Kaiser, C. A., Bretscher, A., Krieger, M., Lodish, H.,Martin, K. C. (2016). Molecular Cell Biology. United Kingdom: W. H. Freeman.
6. Parashar, S., Goel, D. (2013). IPR, Biosafety and Bioethics. India: Pearson Education India.
7. The Role of Intellectual Property Rights in Agriculture and Allied Sciences. (2018). Canada: Apple Academic Press.
8. Xiong, J. (2006). Essential bioinformatics. Spain: Cambridge University Press.
9. Dubey, R. C. (2014). Advanced Biotechnology. India: S. Chand Limited.

BIO 10402- BASIC PRINCIPLES OF METABOLISM

Course Description: This course will provide a basic understanding of metabolism by studying its major pathways, regulation, and molecular components. It will cover the various aspects of metabolism and biochemistry. This course is designed to make students familiarise with basics of metabolism of various biomolecules.

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the different aspects of thermodynamics and bioenergetics	Understand
C.O. 2: Explain the mechanisms of metabolism of various biomolecules	Understand

C.O. 3: Explain why ATP is the energy currency of the cell	Apply
C.O. 4: Describe the characteristics features of anabolic and catabolic pathways	Understand

MAPPING of CO's and PO's

	Program 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

Overview of thermodynamics and bioenergetics: ATP as energy molecules, Role of mitochondria in ATP synthesis, other important high energy compounds and their significance; Laws of thermodynamics, Oxidation-reduction reactions.

MODULE II

Carbohydrate metabolism: Carbohydrate metabolism and energetics: glycolysis, gluconeogenesis and TCA cycle and their significance

MODULE III

Lipid metabolism: Lipid metabolism overview and their significance. Biosynthesis of lipid and beta-oxidation and their relevance

MODULE IV

Amino acid metabolism: Amino acid biosynthesis and catabolism and their significance, Urea cycle and its significance.

MODULE V

Nucleic acid metabolism: Biosynthesis (*de novo* and salvage pathways) and catabolism of nucleic acids and their significance

REFERENCES

1. Nelson, D. L., Cox, M. (2017). Lehninger Principles of Biochemistry: International Edition. United Kingdom: Macmillan Learning.
2. Rodwell, V. W., Weil, P. A., Kennelly, P. J., Bender, D., Botham, K. M. (2018). Harper's Illustrated Biochemistry Thirty-First Edition. United States: McGraw Hill LLC.
3. Voet, D., Voet, J. G. (2021). Biochemistry. Singapore: John Wiley & Sons, Limited.
4. Holtzhauer, M. (2006). Basic methods for the biochemical lab. Germany: Springer.
5. Satyanarayana, U. (2017). Biochemistry - E-book. India: Elsevier Health Sciences.

BIO 10403- ESSENTIAL CELL BIOLOGY

Course description: The objective of the course is to help the students to learn and develop an understanding of a cell as a basic unit of life. This course is designed to enable them to understand the functions of cellular organelles and how a cell carries out and regulates cellular functions. The course will also provide an overview of classical and modern cell biology-based techniques.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the fundamental principles of cell biology.	Understand
C.O. 2: Identify and differentiate the cellular organelles using microscopy.	Analyze
C.O. 3: Identify and differentiate plant, animal and microbial cells based on morphological features and size.	Analyze
C.O. 4: Evaluate how cells grow, divide, survive and die using staining techniques.	Evaluate
C.O. 5: Describe the process of cell signaling and its role in cellular functions	Understand
C.O. 6: State how defects in the functioning of cell organelles and regulation of cellular processes can develop into diseases.	Remember
C.O. 7: List the advances made in the field of cell biology and their applications.	Remember

MAPPING of CO's and PO's

	Program 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

History, development and scope of cell biology; discovery of cells; cell theory and its modern version. Cell and its components: basic types of cells- prokaryotic and eukaryotic, nature and comparison. Ultra-structural organization and functions: Plasma membrane- ultrastructure- fluid mosaic model, functions of the plasma membrane.

MODULE II

Cellular Organelles and their functions: Mitochondria, Endoplasmic reticulum, Golgi bodies, Lysosomes, Microbodies, Ribosomes, Proteasomes, Centrioles, Cytoskeleton, Nucleus-nuclear envelope and Nucleolus, chromosomes, Nucleoproteins, Nucleosome model of DNA organization, structural and numerical variations of chromosomes, Polytene, Lamp brush and B chromosomes.

MODULE III

Histology-Animal histology: Tissues: Epithelial tissue; types, characteristics and functions, Blood, Bone, Cartilage and Adipose tissues, Muscle tissue; Cellular and molecular mechanism of muscle contraction, Nervous tissue. Plant histology- Plant tissues; meristematic & permanent (simple complex tissues), tissue systems.

MODULE IV

Overview of cell signaling, communication between cells, plasma membrane and nuclear receptors; hormones; ion channels; secondary messengers; Cell Division: cell cycle- Gl, S, G2, and M phases, amitosis. Mitosis & Meiosis; Cell cycle and Regulation, cancer cells, and cell death.

MODULE V

Cell Biology Techniques: Cell Isolation (plants and Animals), Microscopy and Micrometry: Fixed and live-cell imaging, Radioisotopes, Fluorescent Probes/Dyes as tools to study cellular functions, basics of FACS.

REFERENCES:

1. Campbell Biology, 10th Edition. Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson
2. Biology: A Global Approach (Paperback) by Jane B. Reece, Steven A. Wasserman 3) Molecular Biology of Gene: Watson et al.,
3. Molecular Cell Biology: By Darnell, Lodish, Baltimore
4. Concepts of Genetics William S Klug and M. R. Cummings, Gerald Karp, Cell Biology
5. Wayne M. Becker et al., World of the Cell
6. Bruce Alberts et al., Essential Cell Biology 4th Edition
7. Richard Goldsby and Thomas J Kindt, Kuby Immunology
8. Cooper, Geoffrey M., and Robert E. Hausman. 2009. *The cell: a molecular approach*. Washington, D.C.: ASM Press.
9. De Robertis & De Robertis: Cell & Molecular Biology, Lea & Febiger, 1987

BIO 10404- ANIMAL FORMS AND FUNCTIONS

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 a 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 the digestive system and its anatomical specializations concerning 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

	Program 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

Modes of Feeding and Digestion: Feeding mechanisms: suspension, deposit, cropping and sucking (herbivorous) and raptorial (carnivorous), Intracellular and extracellular digestion: food vacuole and gastrovascular cavity, Types of excretion and Mode of Excretion Open tubular: metanephridia, Closed saccular: protonephridia, Malpighian tubules and kidney.

MODULE II

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

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

MODULE IV
Nervous system: Patterns of the nervous system in non-chordates, Organization of the nervous system in vertebrates: central and autonomic system, Receptors and sense organs, Phonoreception in fish and mammals, Photoreception in insects and mammals

MODULE V
Reproduction Types of asexual reproduction: fission, regeneration and parthenogenesis, Sexual reproduction: primary and accessory sex organs and their 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: Textbook of Zoology, Vol. II (2005, Macmillan)
7. Purves et al: Life-the Science of Biology, (7th ed. 2004, Sinauer)
8. Tortora and Anagnostakos: Principles of Anatomy and Physiology (6th ed. 1986, Harper & Row).
9. Schmidt Nielson: Animal Physiology (5th ed. 2005, Cambridge)

BIO 10405- CELL BIOLOGY AND BIOCHEMISTRY LAB

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Manipulating DNA molecule with restriction enzymes	Apply
C.O. 2: Demonstrate the steps involved in molecular cloning and transformation	Analyze
C.O. 3: Evaluate the application of various database	Analyze
C.O. 4: Apply bioinformatic tools for sequence alignments	Apply

MAPPING of CO’s and PO’s

	Program 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	

C.O.3					x	
C.O.4					x	

1. Use of restriction enzymes- Single and double digestion
2. Plasmid DNA isolation and restriction
3. Calculation of the transformation efficiency
4. Agrobacterium bacterium-mediated gene transfer
5. Quantitative analysis of biomolecules
6. Experimental demonstration of Hill's reaction
7. Staining and observation of various organelles under the microscope
8. Imaging of Lampbrush and polytene chromosomes
9. Stages of Mitosis (Onion tip) and meiosis
10. Blood smear preparation and its analysis.
11. Imaging of various murine cell types: Epithelial cells, endothelial cells, neuronal cells, immune cells.
12. Identifying permanent tissues from plant sections (parenchyma, collenchyma, sclerenchyma, xylem vessels)
13. Identifying apoptotic and necrotic cells by the cell staining procedure

Semester V

SEMESTER V

BIO 10501- PLANT DIVERSITY (Algae/Fungi/Bryophytes/Pteridophytes/Paleobotany)

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 are treated as a separate kingdom and not included in the plant and animal kingdom	Understand
C.O. 2: Classify algae, fungi, bryophytes, pteridophytes	Understand
C.O. 3: Differentiate fungi, lichens, bryophytes and pteridophytes based on morphology	analyse
C.O. 4: Identify various plants and their organization in nature through field trips	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

	Program 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

Algae: Classification (F.E Fritsch), Principles and modern trends in the taxonomy of algae. Morphology, anatomy, life cycle and reproductive biology of a) Cyanophyceae- Nostoc b) Chlorophyceae-Chlorella, Volvox, Oedogonium and Chara c) Xanthophyceae-Vaucheria d) Bacillariophyceae-Pinnularia e) Phaeophyceae-Sargassum f) Rhodophyceae- Polysiphonia. Contributions of Indian Algologists. Economic importance of algae. Applied aspects: Biofuel production, food supplements, pharmaceutical industries, algal blooms, commercial cultivation of algae.

MODULE II

Fungi: 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

Bryophytes: classification- general account, Study of habit, thallus organization, vegetative and sexual reproduction, and alternation of generation of the following types (Developmental details are not required), Type study: *Riccia, Marchantia, Anthoceros and Funaria*. Economic importance of Bryophytes

MODULE IV

Pteridophytes: Classification, General characters, morphological and anatomical features, life cycle and reproductive biology, Type study: *Psilotum*, *Selaginella*, *Pteris* and *Marsilea*, Stelar evolution in Pteridophytes, Economic importance of Pteridophytes.

MODULE V

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 Delhi
2. Parihar N.S. – An introduction to Bryophyta - Central Book Depot. Allahabad
3. Vasishta B. R. - Bryophyta - S. Chand and Co. New Delhi
4. Coulter. J. M. - and Chamberlain C. J. (1958) – Morphology of Gymnosperms - Central Book Depot, Allahabad
5. Gupta V.K. and Varshneya U. D (1967) – An Introduction to Gymnosperms – Kedarnath, Ramnath – Meerut.
6. Smith G.M. (1955) - Cryptogamic Botany – Vol.II – Mc Graw Hill Co. New Delhi
7. Sporne K. R. (1967) - Morphology of Gymnosperms - Hutchin University Library, London
8. Vashista B. R. (1993) - Pteridophyta – S. Chand and co. New Delhi
9. Vashista B. R. (1993) Gymnosperms - S. Chand and co. New Delhi
10. Andrews H.N. (1967) - Studies on Palaeobotany – C. J. Felix.
11. Arnold C. A (1947) - Introduction to Palaeobotany - McGraw Hill Co. New Delhi.

BIO 10502- NON-CHORDATA

Course description: The course will help the students to understand the features of the Kingdom Animalia and the systematic organization of the animals based on their evolutionary relationships, structural and functional affinities. The course will also make the students aware of the characteristic morphological and anatomical features of diverse animals; the economic, ecological and medical significance of various animals in human life; and will create interest among them to explore the animal diversity in nature.

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: Classify non-chordates as per their distinguishing features.	Understand
C.O. 4: Examine the anatomy of different classes of non-chordates that enables survival advantages in their habitat	Analyse
C.O. 5: Identify various non-chordates based on systematics	Remember
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

	Program 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

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

MODULE II

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

MODULE III

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

MODULE IV

Concept of Minor Phylum and their importance in the study of non-chordate evolution; General characteristics of Aschelminthes (Rotifera, Acanthocephala, Nematoda, Nematomorpha, Priapulida, Kinorhyncha, Gastrotricha), Ectoprocta; Chaetognatha; Echiura, Sipunculida, Pogonophora; Lophophorata (Phoronida, Brachiopoda, Bryozoa); Hemichordata

MODULE V

Reproduction in Protozoans; Theories on the origin of 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. Moore: An introduction to the invertebrates (2001Cambridge)
3. Ekambaranath Ayar: A manual of Zoology, Part I – Invertebrata, (1973, S. Vishwanathan)
4. Kotpal, Agarwal and Khetrapal: Modern Textbook of Zoology: Invertebrate, (1976, Rastogi)
5. Marshall: Parker and Haswell Textbook of Zoology, Vol. I (7th ed. 1972, Macmillan)
6. Nigam: Biology of Non-chordates (1985, S. Chand)
7. Jordon and Verma: Invertebrate Zoology (1995, S. Chand)
8. Millar and Harley: Zoology (6th ed. 2005, Brown)

BIO 10503- PLANT DIVERSITY II (Gymnosperms and Angiosperms)

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, and ethnic groups, and 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	Analyze
C.O. 3: Compare the diversity among plants based on morphology, anatomy, life cycle.	Analyze

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

	Program 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

Gymnosperms: Classification, general features, morphology, anatomy, life cycle and reproductive biology of Cycadopsida-*Cycas,* Coniferopsida-*Pinus* and Gnetopsida-*Gnetum*. Evolutionary trends in gymnosperms and their economic importance.

MODULE II

Angiosperms: Principles and importance of taxonomy, Herbarium technique, BSI and ICBN. Systems of classification. Outline classification of Bentham & Hooker and Cronquist. APG systems of classification. The concept of taxon and Taxonomic hierarchy, plant nomenclature. A brief reference to the citation of the author. Chemotaxonomy.

MODULE III

Morphology: Morphology of root, stem, leaves and inflorescence. Floral morphology and structure, the symmetry of flower, aestivation, placentation; floral diagram and floral formula, Fruit types: simple, aggregate, and multiple. Seeds: albuminous and exalbuminous. Palynology: Pollen architecture, Pollen transfer, Pollen–pistil interaction. Pollination and its types. Pollen allergy, palynological calendars and pollen analysis of honey.

MODULE IV

Economic botany: Binomial, family and morphology of useful parts of Maize, soya bean, sugarcane, cocoa, tea, pepper, cardamom, potato, banana, mango, cashew nut, tomato, vinca, opium, teakwood.

MODULE V

Ethnobotany: Ethnobotany and Folk medicines. Ethnobotany in India, Methods to study ethnobotany -Fieldwork, Herbarium, Ancient Literature, Archaeological findings, temples and sacred places. Applications of Ethnobotany: Medicinal plants of tribals with reference to Thuthi, Kadukkai, Perandai, Avarai, Kandankathari, Oomathai, Veliparuthi, Asparagus and Boerhaavia. Legal aspects-biopiracy, IPR & traditional knowledge,

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2. Pandey SN and Misra SP, 2008 Taxonomy of Angiospenus; Ane Books Pvt. Ltd.
3. Verma V, 2009 Textbook of Economic Botany; Ane Books Pvt. Ltd.
4. Kapoor LD, 2001 Handbook of Ayurvedic Medicinal Plants, CRC Press New York, Ane Books Pvt. Ltd
5. Jones, S.B. Jr. and Luchsinger, A.E. 1986. Plant Systematics (2nd edition). McGraw-Hill Book Co., New York.
6. Lawrence. G.H.M. 1951. Taxonomy of Vascular Plants. Macmillan, New York.
7. Naik, V.N. 1984. Taxonomy of Angiosperms. Tata McGraw Hill, New York.
8. Singh. G. 1999. Plant Systematics: Theory and practice Oxford & IBH Pvt, Ltd.New Delhi.
9. Nordenstam. B.., El-Gazaly, G. and Kassas. M. 2000. Plant Systematics for 21st Century
10. S.K. Jain. Glimpses of Ethnobotany. Oxford and IBH Publishing Company, New Delhi.

BIO 10504- ELECTIVE

BIO 10505- PLANT AND ANIMAL LAB I

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: Differentiate fungi, lichens, bryophytes and pteridophytes based on morphology	Analyse
C.O. 4: Identify various plants and their organization in nature through field trips	Remember
C.O. 5: Collection and conservation of plant samples	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

Program 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	

Plant Diversity

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. *Cycas*- T.S of leaf, T.S. of the coralloid root, Male and female cone, ovule (LS)
10. *Pinus*- T.S. of the stem, T.S. of the needle, male and female cone VS
11. Students must submit practical records, Herbarium sheets (15 No's) and Field books at the time of practical examination.
12. Identify the economic products obtained from the plants mentioned under Economic Botany
13. Critical notes on plants of ethnobotanical relevance mentioned in the syllabus.

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. Honeybee – mouthparts/mosquito - mouthparts
5. Prawn – appendages (Any Three- Maxillipeds1,2,3, Chelate leg, First abdominal appendage) nervous system
6. Spot Identification: Taxonomy Identification, Classification up to class and a brief note of the following specimens.

I. Protista – Actinophrys, Noctiluca, Paramecium, Opalina – any 2
II. Phylum Porifera – Euplectella, Spongilla- any 1
III. Phylum Cnidaria – Hydra, Obelia, Physalia, Aurelia, Sea anemone, Madrepora – any 3
IV. Phylum Nematoda – Ascaris- male and female (entire)
V. Phylum Platyhelminthes – Bipalium, Fasciola, Taenia solium – any 1
VI. Phylum Annelida – Earthworm, Nereis, Leech, Aphrodite, Arenicola – any 1

VII. Phylum Onychophora – Peripatus
VIII. Phylum Arthropoda – Cockroach, Limulus, Eupagurus, Sacculina, Honeybee, Lepisma, Scorpion – any 3
IX. Phylum Mollusca – Chiton, Pila, Xancus, Dentalium, Perna, Mytilus, Teredo, Sepia, Octopus. – any 2
X. Phylum Echinodermata – Starfish, Brittle star, Sea urchin, Sea cucumber, Sea lily – any 2

Chordata

1. *Branchiostoma*- External features; Mounting of the oral hood, velum and pharyngeal wall

Study of the following slides: T.S. through the oral hood, midgut diverticulum, pharyngeal region, gonads and post-oral region of the intestine; study of *Pyrosoma, Salpa, Doliolum*

2. Mounting of the cycloid and ctenoid scales; mounting of chromatophores of fish; study of different types of feather: Contour, filoplume and down feathers
3. Vascular system- Heart and afferent and efferent branchial vessels of Mystus/ *Cirrhinus sp.;* Arterial and venous systems of rat
4. Respiratory system: Accessory respiratory organs of *Heteropneustes, Channa, Clarias*
5. Nervous system of a fish

6. Histology of tooth, tongue, 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*
    2. Chondrichthyes: *Scoliodon*
    3. Osteichthyes
    4. Amphibia
    5. Reptilia
    6. Aves
    7. Mammalia

Semester VI

SEMESTER VI

BIO 10601- EVOLUTION AND DEVELOPMENTAL BIOLOGY

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 species and the environment they live in	Understand
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

	Program 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

Biochemical and genomic evolution: The evolutionary history of proteins, Evolution of gene, gene families, molecular drive, Amino acid sequence divergence in proteins, Nucleotide sequence divergence in DNA noncoding RNA, micro RNAs, the phylogenetic utility of RNA structures, Hitchhiker's Guide to evolving networks, protein-protein interaction network, the evolution of metabolic networks, and concept of molecular clock, Outline of origin of prokaryotic and eukaryotic genomes

MODULE II

Origin of Higher Categories, Origin of Metazoa, theories of origin, Origin and evolution of Trilobites, vertebrate groups- Pisces, Amphibia, Reptilia, Aves and Mammals. The evolutionary history of neural integration, endocrine systems, Hormones Phylogenetic gradualism, and punctuated equilibrium, Micro and Macroevolution. Stages in Primate Evolution- Prosimii, Anthropoidea and Hominids. Factors in human origin-Hominid fossils, Cytogenetic and Molecular basis of the origin of the man-African origin of modern man- Mitochondrial Eve, Y chromosomal Adam, - early migration, hunter-gatherer societies.

MODULE III

Developmental Biology: Introduction theories- Preformation, Epigenesis, Recapitulation and Germplasm. Subdivisions of Developmental biology. Spermatogenesis and oogenesis, the structure of Graafian follicle, typical egg and sperm, Polarity of egg, egg envelops; classification of eggs based on different criteria. Fertilization: Agglutination, sperm penetration, activation of egg, amphimixis; physiological and biochemical changes during and after fertilization. Parthenogenesis, Cleavage, Morula formation, blastulation and blastocyst.

MODULE IV

Cell differentiation: totipotency, 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

Human - implantation, pregnancy, parturition. Placentation in mammals - different types of the placenta, functions, Teratology. Experimental embryology, developmental disorders. In vitro fertilization and embryo transfer experiments in mammals and test-tube babies, prenatal diagnosis, and sex determination methods – amniocentesis chorionic villus sampling, ultrasound scanning. Embryonic and adult stem cell research and stem cell therapy.

REFERENCES

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2. Freeman S. and Jon C. Herron (1998): Evolutionary Analysis. Prentice-Hall
3. Futuyma D. J. (1998): Evolutionary Biology. Sinauer
4. Hartl D. L. and A. G. Clark (1989 & 1997): Principles of Population Genetics. Sinauer
5. Li Wen-Hsiung and Dan Graur (1991): Fundamentals of Molecular Evolution. Sinauer
6. Strickberger M. W. (2000): Evolution. Jones and Bartlett
7. White M. J. D. (1978): Modes of Speciation. Freeman
8. P.C. Jain. (2007). Elements of Developmental Biology, 6th Edn. Rastogi Publications

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2. Gilbert. S.F. (2000). Developmental Biology. Sinauer Associates, Inc. Publishers.
3. Huettner, A.F. (1959). Comparative Vertebrate Embryology. MacMillan.
4. Nelson. (1960). Comparative Embryology of Vertebrates. MacMillan.

BIO 10602- PARASITOLOGY AND IMMUNOLOGY

Course description: Parasitology will enable us to diagnose parasites correctly, understand their life cycle and control them effectively and use some of them as biocontrol agents. Parasitology; especially the study of the life cycles of parasites; has helped in defying the stigmas and religious taboos for many societies making free many of the people from superstition and ill health. The course shall surely skill the students to see, appreciate and understand the diversity of parasites in the whole spectrum of the study of life. Also, provide an overview on the immune system and its function. The course shall also make the students aware of the possible scopes of the subject which include research and applied aspects including entrepreneurial works.

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 a parasitic attack, Diagnosis, Prophylaxis and Treatment of parasitic infections.	Understand
C.O. 3: Discuss the basics of immunology and List immunological components	Understand
C.O. 4: Differentiate various blood cells by microscopy	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

	Program 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

Introduction to Parasitology Brief introduction of Parasitism, Parasite, Parasitoid and Vectors, Host-parasite relationship, Ecology of parasites, Population dynamics of parasite and establishment of the parasite population in the host body, the evolution of parasitism, evolution and coevolution of parasite with respect to host strategy, Important case studies in the field of Parasitology including some historical events such as the role of the mosquito control and the successful completion of the construction of the Panama canal.

MODULE II

Parasitic Protists Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Entamoeba histolytica*, *Giardia intestinalis*, *Trypanosoma gambiense*, *Leishmania donovani*, *Plasmodium vivax*. Parasitic Platyhelminthes Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Fasciolopsis buski, Schistosoma haematobium, Taenia solium* and *Hymenolepis nana*.

MODULE III

Parasitic Nematodes Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Ascaris lumbricoides*, *Ancylostoma duodenale*, *Wuchereria bancrofti* and *Trichinella spiralis*. Study of the structure, lifecycle and importance of *Meloidogyne* (Root-knot nematode), Pratylencus (Lesionnematode), Parasitic Arthropoda Biology, importance and control of ticks, mites, *Pediculus humanus, Xenopsylla cheopis* and *Cimex lectularius*. Crustacean parasites. Parasitic Vertebrates A brief account of parasitic vertebrates; Cookiecutter Shark, Candiru, Hood Mockingbird and Vampire bat.

MODULE IV

Introduction, history, development and scope, Immunity: definition, classification of immunity. Innate and adaptive, Components of the Immune system: organs and tissues of the immune system. Antigens and Antibody, epitopes, antibodies (Immunoglobulins) - definition, the general structure of Ig, Ig determinants, precipitation reactions, agglutination reactions, complement fixation, neutralization, opsonization, complement system, major histocompatibility complex (MHC), types of immune responses- humoral immune response, cellular immune response, mention cytokines, define immunological memory, immunological tolerance, and immune suppression.

MODULE V

Hypersensitivity/allergy and Autoimmunity: definitions, classification- types I, II, and III, immunodeficiency diseases, Acquired Immune Deficiency Syndrome (AIDS); Auto immunity-definition, mechanism, mention AI diseases; transplantation immunity, graft versus host reactions, Immunization, and vaccination.

REFERENCES

1. Foundations of Parasitology, Roberts L.S. and Janovy J., McGraw-Hill Publishers, New York, USA.

2. Modern Parasitology: A Textbook of Parasitology, FEG Cox., Wiley-Blackwell, U. K.
3. Parasitology: A Conceptual Approach, Eric S. Loker, Bruce V. Hofkin
4. Kuby Immunology, Richard, Thomas, Barbara, Janis, W. H. Freeman and Company [Latest edition].
5. Immuno Biology- The immune system in health and disease, Janeway, Travers, Walport and Shlomchik, Garland Science Publishing [Latest edition].
6. Essentials of Immunology, David, Brostoff and Roitt, Mosby & Elsevier Publishing
7. Fundamentals of Immunology by William E. Paul, Lippincott Williams & Wilkins Publishing
8. Cellular and Molecular Immunology by Abul K. Abbas, Andrew H. Lichtman, Shiv Pillai, Elsevier Publishing

BIO 10603- CHORDATA

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

MAPPING of CO's and PO's

Program 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

General characteristics, classification of the following up to sub-classes/ orders with examples and affinities of the following: Protochordata (Urochordata, Cephalochordata); Cyclostomata; Pisces; Amphibia; Reptilia; Aves; Mammalia; Origin of vertebrates, lungfishes; Amphibians, birds and mammals.

MODULE II

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

MODULE III

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

MODULE IV

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

MODULE V

General considerations of integumental derivatives Scales, feathers, hair, claws, nails, hoofs, horns, antlers, glands), stomach in ruminants, Parental care in amphibians; snake venom; bird migration; flightless birds; dentition in mammals.

REFERENCES

1. Aiyar. A Manual of Zoology, Vol.2.
2. Kotpal: Modern Textbook of Zoology Vertebrates (2003, Rastogi)
3. Nigam: Biology of Chordates (1983, S Chand)
4. Harvey *et.al*: The Vertebrate Life (2006)
5. Colbert *et.al*: Colbert’s Evolution of the Vertebrates: A History of the Backboned Animals through time (5^{th} ed, 2002, Willey-Liss)
6. Hildebrand: Analysis of Vertebrate Structure (4^{th} 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 (6^{th} ed 1986, CBS Publishing Japan)

11. Sinha, Adhikari & Ganguli: Biology of Animals Vol.II (1988, New Central Book Agency)

BIO 10604- PARASITOLOGY AND IMMUNOLOGY LAB

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

	Program 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					

1. Study of life stages of *Entamoeba histolytica, Giardia intestinalis, Trypanosoma gambiense, Leishmania donovani* and *Plasmodium vivax* through permanent slides/microphotographs.
2. Study of adult and life stages of *Fasciolopsis buski, Schistosoma haematobium, Taenia solium* and *Hymenolepis nana* through permanent slides/microphotographs.

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

BIO 10605- ELECTIVE

Semester VII

SEMESTER VII

BIO10701- CELLULAR METABOLISM

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, and 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 the 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

	Program 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

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, Glyoxylate cycle, Overview on glycoconjugates structure and function, Disorders of Carbohydrate metabolism.

MODULE II

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, and Eicosanoids; Inborn errors of lipid metabolism.

MODULE III

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

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

Photosynthesis and Electron Transport Chain: Biochemical aspects of Reaction centres, 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

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8. Lurton, R. (2010). Clinical Biochemistry.2nd Edition. Viva books.
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10. Cooper T.G. (2015). Tools of Biochemistry.2nd edition, Wiley-Interscience
11.Sadasivam S. and Manickam A. (2009). Biochemical Methods, 2ndedn.New Age International Ltd Publishers.
12. Mu, P., & Plummer, D. T. (1988). Introduction to Practical biochemistry. Tata McGraw-Hill Education.

BIO10702- CELL BIOLOGY

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: Analyze 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

	Program 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

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

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

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

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

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
4. Gerald Karp, Janet Iwasa, Wallace Marshall; Cell Biology (8th Edition); by Wiley; 2018
5. David E. Sadava; Jones & Bartlett Learning, Cell Biology: Organelle Structure and Function; 1993

6. Harvey Lodish; Arnold Berk; Chris A. Kaiser; Monty Krieger; Anthony Bretscher; Hidde Ploegh; Angelika Amon; Kelsey C. Martin; W.H. Freeman; Molecular Cell Biology (8th Edition), 2016
7. Geoffrey M. Cooper, Robert E. Hausman; The Cell: A Molecular Approach (8th Edition) by Sinauer Associates; 2014
8. Jeff Hardin Gregory Paul Bertoni; Becker's World of the Cell, (9th Edition) by Pearson; 2015

BIO 10703- ADVANCED MICROBIOLOGY

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

	Program 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

Bacteriology: Classification, virulence factors, microbial communication system; bacterial quorum sensing; toxin genes, virulence, Biofilms in disease; Pathogenic bacteria and viruses, AMR genes in pathogenesis, plant diseases, microbial diseases in animals, Human Bacterial diseases-Tuberculosis, leprosy, Cholera, Typhoid, Human microbiota and their role in human health, Drug-resistant bacteria, antibiotics and antimicrobial agents.

MODULE II

Virology: Virus and bacteriophages, Viruses and bacteriophages, general properties of viruses, Viral structure, genetic materials, virulence factors, viral metabolism, reproduction, phages, viral structure, the taxonomy of 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:

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

MODULE IV

Microbial genetics: Organization of the bacterial chromosome, Regulation of gene expression, Induction, and repression- the lac operon, regulatory mutants of the lac operon. Quorum sensing and cross-talks. Importance and uses of mutation analysis. Isolation and identification of mutants. Extrachromosomal inheritance. Gene transfer and mapping by conjugation, Gene transfer by transformation and transduction, Transposons. Genetics of bacteriophages- lytic and lysogenic cycles

MODULE V

Genetic analysis of bacteria: Gene mapping, conjugational analysis, transformation and transduction, Molecular techniques in gene mapping-gene libraries, Restriction mapping and PFGE, Diagnosis and epidemiology-gene probes for detection of pathogens, Detection of virulence genes; diagnostic use of PCR, molecular epidemiology. **Genetic analysis of phages** – complementation and recombination tests with phages. Genetic experiments with the rII genes of phage T4. Deciphering the genetic code using rII mutants. Constructing phage genetic linkage maps using two-factor and three-factor crosses.
Assays to 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. Marjorie Kelly Cowan (2015). Microbiology: A Systems Approach,3rd edition, McGraw-Hill Higher Education.
10. Booth S J. (2010). Microbiology: Pearls of Wisdom, 2nd edition, Scientific book center.
11. Sherwood, L., Willey, J. M., &Woolverton, C. (2011). Prescott's Microbiology. McGraw-Hill.

BIO 10704- MOLECULAR BIOLOGY

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	Analyze
C.O. 3: Analyze experimental data to explain the reasons for observed changes in gene expression and activity in cells	Analyze
C.O. 4: Select appropriate model systems for studying different molecular biological processes	Analyze
C.O. 5: Analyze and understand journal articles containing original research	Analyze

MAPPING of CO's and PO's

	Program 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

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

Maintenance of Genome: Genome structure, Chromatin and the Nucleosome; Replication of DNA, Extrachromosomal Replicons; Mutability and Repair of DNA, Homologous Recombination; Site-specific recombination, Transposition of DNA

MODULE III

Transcription and Translation of Genetic Information: Mechanism of Transcription; RNA polymerases in eukaryotes, general and specific transcription factors, assembly of pre-initiation complex, enhanceosomes, elongation factors and elongation; Types of introns and mechanism of splicing. Translation; The Genetic Code.

MODULE IV

Promoter analysis and characterization: Deletion mapping, Transient/stable expression system, S1/RNase mapping, EMSA, DNase I 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

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- ADVANCED BIOLOGY LAB- I

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 various organelles of cells using imaging	Analyze
C.O. 3: Identity carbohydrates (sugars), amino acids/proteins, cholesterol and triglycerides and nucleic acids	Remember and Analyze
C.O. 4: Apply recombinant DNA technology technique to demonstrate the bacterial transformation in *E. coli*	Apply
C.O. 5: Apply chromatographic and electrophoretic techniques for purification and molecular analysis of the proteins	Apply
C.O. 6: Evaluate the physical and chemical properties of DNA /proteins	Evaluate
C.O. 7: Analyze the importance of enzyme inhibitors in biochemical pathways	Analyze

MAPPING of CO's and PO's

	Program 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>Cellular metabolism</u>

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 carbohydrates (sugars), amino acids/proteins, cholesterol and triglycerides and nucleic acids

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

Molecular Biology

1. DNA and RNA isolation
2. Primer designing
3. PCR and semi-quantitative RT PCR
4. Analysis of PCR products on an agarose gel.
5. Southern/Northern/Western hybridization techniques
6. Restriction digestion and analysis
7. Competent cell preparation and analysis of efficiency

Advanced Microbiology

1. Media preparation, microbial culture (bacterial and fungal).
2. Growth curves, preservation of the bacteria, plating, dilution plating.
3. Effect of temperature, pH, salts and other stress factors on bacterial growth.
4. Isolation of bacteria from various surroundings, Identification of bacteria by biochemical assays and Gram staining.
5. Antibiotic or drug inhibition assays.
6. Transformation and competent cell preparation studying *E. coli* as a model microorganism for R&D.
7. Mammalian virus culture and titration.

BIO 10706- PROFESSIONAL AND CAREER ASPECTS IN BIOTECHNOLOGY

BIO 10707- ELECTIVE

Semester VIII

SEMESTER VIII

BSc HONORS WITH RESEARCH

BIO 10801- ELECTIVE

BIO 10802- PROJECT WITH REPORT

BSc HONORS

BIO 10801- ENZYMOLOGY

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 purification of enzymes from different sources.	Understand
C.O. 2: Compare the structure, and general properties of enzymes to their mechanism of action.	Analyze
C.O. 3: Analyze 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

	Program 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
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
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
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
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
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.

REFERENCES
1. Rosevear, A. et al (1987). Immobilized enzymes and cells: Adam Higher imprint IOP Publishing.
2. Donald, F. C. (1992). Clinical Chemistry, A fundamental textbook. Saunders Company.
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

BIO 10802- PLANT PHYSIOLOGY AND BIOCHEMISTRY

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

	Program 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

Physiology: General Introduction on physiological processes, their significance and applications, Water relations of plants, physical aspects of absorption-imbibition, diffusion, and osmosis. Water potential and osmotic potential, Plasmolysis and its significance, Mechanism of water absorption-active and passive absorption, root pressure, aquaporins. Pathway of water across root cells, Ascent of sap-vital and physical theories. Transpiration-cuticular, lenticular and stomatal. Mechanism-theories -starch sugar hypothesis, potassium -ion theory. Significance of transpiration, anti-transpirants, Guttation and its significance.

MODULE II

Mineral nutrition: Gross chemical analysis of the plant body, ash analysis, criteria for the essentiality of elements, macro and microelements, the role of essential elements and their deficiency symptoms. Culture methods-sand culture, hydroponics and aeroponics. Mechanism of mineral absorption (a) passive absorption-ion exchange and Donnan equilibrium (b) active absorption -carrier concept, Lundegardh hypothesis, Translocation of solutes: Pathway of movement, phloem transport, mechanism of transport

MODULE III

Plant movements: Tropic and nastic movements. Circadian rhythm and biological clock. Stress Physiology: Types of stress- water, temperature, salt, stresses caused by pests and pathogens and pollutants, Plant defense systems and mechanisms. Growth regulators-Auxins, Gibberellins, Cytokinins, Ethylene, Abscisic acid-synthetic plant hormones-practical applications. Senescence and abscission. Photoperiodism. Vernalization, Dormancy.

MODULE IV

Photosynthesis, structure and function of the chloroplast, Fluorescence and phosphorescence, red drop, Emersion effect; Two pigment systems; Mechanism of photosynthesis-Light reaction, Calvin cycle; comparative study of C3, C4 and CAM plants; photorespiration, Factors affecting photosynthesis-Law of limiting factor, Respiration Energy relation of respiration-RQ and its significance-Factors affecting respiration.

MODULE V

Secondary Metabolites and Nitrogen Fixation: Types, structure, functions, Biosynthesis of Secondary metabolites, economic importance. Plants and Nitrogen: The nitrogen cycle, Nitrogen metabolism: Source of nitrogen, biological nitrogen fixation-symbiotic and asymbiotic. Nitrogen fixation by blue-green algae-rotation of crops. Genetics of N fixation - *Nif* genes and Leghaemoglobin. Biosynthesis of amino acids- reductive amination and transamination.

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.
5. Nelson DL, Cox M M, 1993. Principles of Biochemistry. MacMillan Publications.
6. Pandey S N, Sinha B K, 2006. Plant Physiology. Vikas Publishing House Pvt. Ltd.
7. Sadasivam S, Manickan A, 1996. Biochemical Methods. New Age International Ltd. New Delhi.
8. Salisbury F B, Ross C W, 1992. Plant Physiology. CBS Publishers and Distributors, Delhi.
9. Srivastava H S, 2005. Plant Physiology. Rastogi publications, Meerut.
10. Verma V, 2007. Textbook of Plant Physiology. Ane Books India, New Delhi.

BIO 10803- HUMAN PHYSIOLOGY AND ENDOCRINOLOGY

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

	Program 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

Nutritional physiology: Structure and digestive system: General introduction, types of nutrition, mechanical and chemical changes of food in the alimentary canal, balanced diet, nutritional disorders-PEM, vitamin and mineral deficiency, hormonal control of digestion Circulatory physiology: Structure of heart, Blood composition and functions of blood plasma and formed elements, blood groups, mechanism of blood clotting, intrinsic and extrinsic pathways, disorders of blood clotting, anticoagulants, heartbeat, conducting system and pacemaker, pulse and blood pressure, clinical significance, control of cardiac activity, common cardiovascular diseases-arteriosclerosis, atherosclerosis, myocardial infarction, electrocardiogram, angiogram, angioplasty, Lymph and lymphatic system.

MODULE II

Respiratory physiology: Structure of lungs. Gas exchange, respiratory pigments-structure of haemoglobin, transport of oxygen-Oxyhaemoglobin curve, Bohn effect, transport of CO_2-carbonic acid, carbamino haemoglobin, bicarbonate and chloride shift, carbon monoxide poisoning, bronchitis, asthma, physiological effects of smoking, fibrosis

Renal Physiology: Structure of kidney. Nephron structure, urine formation, counter current multiplier system, the role of the kidney in osmoregulation, renal disorders-nephritis, haematuria, renal calculi, acidosis, and alkalosis-, fibrosis, Dialysis, and kidney transplantation

MODULE III

Muscle Physiology: Brief account of types of muscles, fast and slow twitch muscles, red and white muscles, the ultrastructure of striated muscle fibre, muscle proteins, simple muscle twitch, summation, tetanus, tonus, ALL or None Law, fatigue, oxygen belt, rigor mortis, physiological and biochemical events in muscle contraction.

Sensory physiology: Structure of eye and ear. Physiology of vision, visual elements and pigments, photochemistry of vision. Eye defects-myopia, hyperopia, presbyopia, astigmatism, cataract. Structure of ear and mechanism of hearing, hearing impairments-deafness, labyrinthine disease. olfactory, gustatory, and tactile sense organs

MODULE IV

Nerve Physiology: Structure of brain, Neurons-structure, types of neurons. 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

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. Eckert, R. and D. Randell. (1987). Animal Physiology, CBS Publishers and Distributors N. Delhi.
2. Ganong, W.F. (2003), Review of Medical Physiology, McGraw Hill, New Delhi.
3. Hoar, W.S. (1975). General and Comparative Physiology, Prentice-Hall.
4. Mac. Eleroy, W.D. (1971). Cell Physiology and Biochemistry. Prentice-Hall of India Ltd.
5. Nagabhushanan, R., Kaobarkar M.S. and Sarojini, R. (1983). A textbook of animal physiology, Oxford IBH Publishing Co., New Delhi.
6. Rama Rao, V., First aid in accidents, Srikrishnan Brothers, Thambuchetty Street, Madras.
7. Schmidt-Nielson K. (2002). Animal Physiology, Prentice Hall India Ltd.
8. Sebastian, M.M. Animal Physiology. Dona Publications, Changanacherry.
9. St. John ambulance associations' textbooks (a) First aid to the injured (b) A preliminary course of first aid to the injured.
10. Subramanyan, S. and Madhavankutty, K. (1977). The textbook of physiology, Orient Longman Ltd., New Delhi.

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- ELECTIVE

BIO 10805- ADVANCED BIOLOGY LAB- II

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: Evaluate the total protein content in samples using biochemical techniques	Evaluate
C.O. 3: Identity carbohydrates (sugars), amino acids/proteins, 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

Program 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	

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.

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, and absorption spectra of chlorophyll and carotenoids using different solvents.
5. Hill activity by DCPIP/ ferricyanide reduction.
6. Setting up of Plant Physiology experiments.

Human Physiology and Endocrinology

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, and 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

Semester IX

SEMESTER IX

BIO10901- IMMUNOLOGY

Course Description: This course is intended to provide a solid grounding in immunology, starting with the basic concepts and proceeding to a deeper understanding of the mechanisms of immune functioning. Special emphasis is given to the 'teamwork' in immune responses. The course also underscores how the system can go wrong, and how it can be corrected or managed using innovative technology. The recently enhanced appreciation of the pre-eminence of the innate immune system, the importance of the intestinal immune system, and the immunomodulatory potential of the gut microbiota are also highlighted. The course also points out the tremendous scope for basic and applied immunological research.

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 'teamwork' fashion, and how it is regulated.	Understand
C.O.3. Explain/describe/discuss how the immune system can go wrong, and what types of immuno-pathologies result.	Understand
C.O. 4. Apply appropriate strategies, techniques, and technologies in the management of immune system disorders.	Apply
C.O. 5. Analyze the intricate regulatory mechanisms of the immune system in specific clinical conditions such as hypersensitivities, immunodeficiencies, and autoimmune diseases.	Apply
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

	Program 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

Introduction to the Immune System: Historical landmarks, branches, broad divisions of the immune system, antigens vs. immunogens, haptens and carriers, epitopes and paratopes. Hematopoiesis, Theories on immune system functioning; Cells and molecules of the immune system, Inflammation: cellular and molecular events, acute and chronic inflammation, contribution to hypersensitivity and autoimmune reactions; Overview of comparative immunology; Overview of psycho-neuro-endocrine-immunology (PNEI); Overview of the circadian – immune connection; Overview of eco immunology.

MODULE II

Humoral and Cell-mediated immune responses: Structure and functions of primary and secondary lymphoid organs; Development, maturation, and functions of T- and B lymphocytes, molecular markers of T- and B- lymphocytes; structure and functions of antibodies, monoclonal vs. polyclonal antibodies, primary and secondary immune responses, clonal selection and clonal expansion, effector cells of the immune system and their specific roles; Generation of receptor diversity (BCR and TCR), subsets of T- and B- cells; Complement: the 3 pathways, regulatory molecules, disorders of the complement system.

MODULE III:

Strategies of immune functioning: MHC/HLA: its structure, functions, and role in antigen presentation, disorders of antigen processing and presentation, the relative risk associated with specific MHC haplotypes; Lymphocyte trafficking and interaction at the germinal centers, the role of HEV in lymphocyte trafficking; Immune responses against bacteria, fungi, parasites, viruses, and prions; Immune evasion strategies of pathogens.

MODULE IV

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

MODULE V

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 concerning hypersensitivity, autoimmunity, transplantation, immunodeficiencies, and tumor immunology.

REFERENCES

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8. Flaherty, D.K Immunology for Pharmacy (2012)., Elsevier

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10. Chapel, H., Haeney, M., Misbah, S., and Snowden, N. Essentials of Clinical Immunology 6th ed. (2014) Wiley Blackwell

BIO10902- GENETIC ENGINEERING

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

MAPPING of CO's and PO's

	Program 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

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

Cloning strategies: Shotgun cloning, amplicon cloning, cDNA cloning and its advantages and disadvantages. Construction of genomic DNA and cDNA libraries: Cloning Vectors -plasmids, lambda phage, SV40, Phagemids; Construction of artificial chromosome vectors-BAC & YAC; Expression systems and their applications.

MODULE III

Recombinant DNA-tailing, cohesive ends: Use of linkers, blunt end methods; In vitro packaging, Host vector systems; Probe construction; recombinant selection and screening; Southern hybridization, Colony hybridization, Plaque hybridization.

MODULE IV

Applications: PCR: RT-PCR, Inverse PCR, Nested PCR, LAMP; Molecular Markers - RAPD, RFLP, DNA fingerprinting, microsatellites and 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

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 and applications.

REFERENCES

1. Winnaker, E.L. (2003). From Genes to Clones. India. VCH Panima Educational Book Agency.

2. Karcher, S.J. (1995). Molecular Biology-A Project Approach (1sted.). Academic Press.
3. Primrose, S.B. (2006). Principles of Gene manipulation and Genomics (7thed.). Blackwell Scientific Publications.
4. Lodish, H., Berk, A, et al. (2016). Molecular Cell Biology (8thed.). W.H. Freeman.
5. Watson, J.D. (2007). Molecular Biology of the Gene (6thed.). Pearson.
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7. Sambrook, J., Fritsch, E. F., & Maniatis, T. (1989). Molecular cloning: a laboratory manual (No. Ed. 2). Cold spring harbor laboratory press.
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10. Kumar, A., Garg, S., Garg N. (2012). Biochemical Test, Principles and Protocols. India: Viva books.

BIO10903- RESEARCH METHODOLOGY

BIO10904- BIOETHICS, BIOSAFETY and INTELLECUAL PROPERTY RIGHTS

Course Description: This course introduces bioethics, biosafety and 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 rDNA 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

	Program 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

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

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

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

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

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

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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.
4. Bioethics - An introduction, Marianne Talbot, 2012, Cambridge University Press.
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BIO10905- ELECTIVE

BIO 10906- ADVANCED BIOLOGY LAB- III

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 immune electrophoresis	Remember
C.O. 5: To apply knowledge of molecular biology, immunogenetics to detect specific proteins using western blotting techniques	Apply

C.O. 6: To evaluate and quantify 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

	Program 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)

<u>Genetic Engineering</u>

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)

Semester X

SEMESTER X

BIO10905- PROJECT PRESENTATION AND VIVA VOCE

Elective Courses

1. Biodegradation and Solid Waste Management
2. Bioenergy
3. Biophysics and Bioinstrumentation
4. Biostatistics
5. Cancer Biology
6. Diagnostic and Pharmaceutical Microbiology
7. Ecology
8. Entomology
9. Environmental Microbiology
10. Ethology and chronobiology
11. Food Microbiology
12. Food nutrition and health
13. Forestry/Wildlife
14. Industrial and Environmental Biotechnology
15. Industrial Microbiology
16. Innovation and Entrepreneurship
17. Medical and Animal Biotechnology
18. Molecular Taxonomy
19. Molecular Virology
20. Nanotechnology
21. Neurobiology
22. Next generation sequencing and data analysis
23. Plant Biotechnology
24. Plant-Microbe Interactions
25. RNA Interference and genome editing
26. Stem Cells and Regenerative Medicines

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DEPARTMENT OF APPLIED CHEMISTRY

Scheme of Examination and Syllabus for the Five Year Integrated M.Sc. Chemistry Approved by the Combined Board of Studies in Physical and Mathematical Sciences and Chemical and Biological Sciences on 30-06-2023

(From 2023 admission onwards)

SEMESTER: 1

Semester Credit: 22 (Core: 19; Elective: 3) Cumulative Credit: 22

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
ENG10101	English – I	Core (AEC 1)	2	2-0-0	50	50	100
MAL10101 HIN10101 GER10101	**Language** Malayalam – I Hindi – I German – I	Core (AEC 2)	2	2-0-0	50	50	100
CHE 10101	General Chemistry I	Core* (MDC)	3	3-1-0	50	50	100
CHE 10102	Quantitative Analysis Lab	Core*	2	0-0-4	100	-	100
CHE 10103	Chemistry in Everyday Life	Core	2	2-1-0	50	50	100
MAT 10101	Calculus I	Interdepartmental Core	3	3-1-0	50	50	100
PHY 10101	General Physics I	Interdepartmental Core	3	3-1-0	50	50	100
PHY 10102	Physics Lab I (Mechanics)	Interdepartmental Core	2	0-0-4	100	-	100
BIO 10103	General Biology	MDC**	3	3-1-0	50	50	100
CSP 10101	Computer Science I	MDC**	3	3-1-0	50	50	100
MAT 10103	Mathematical Methods I	MDC**	3	3-1-0	50	50	100
STAT 10101	Statistical Methods for Data	MDC**	3	3-1-0	50	50	100

AEC – Ability enhancement Course; MDC – Multidisciplinary Course; VAC – Value Added Course; SEC – Skill Enhancement Course

- Student shall select any one language- Malayalam/Hindi/German
- * Will also be offered as an interdepartmental core/MDC
- ** Student shall select any one MDC

Total Credits in Major (Chemistry) -7

SEMESTER: 2

Semester Credit: 22 (Core: 19; Elective: 3) Cumulative Credit: 44

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
ENG10201	English – II	Core (AEC 3)	2	2-0-0	50	50	100
MAL10201 HIN10201 GER10201	**Language** Malayalam – II Hindi – II German – II	Core (AEC 4)	2	2-0-0	50	50	100
CHE10201	General Chemistry II	Core* (MDC)	3	3-1-0	50	50	100
CHE10202	Inorganic Qualitative Analysis Lab	Core*	2	0-0-4	100	-	100
CHE10203	Industrial applications of petrochemicals and petroleum products	Core	2	2-1-0	50	50	100
MAT 10201	Calculus II	Interdepartmental Core	3	3-1-0	50	50	100
PHY 10201	General Physics II	Interdepartmental Core	3	3-1-0	50	50	100
PHY 10202	Physics Lab II (Waves and Optics)	Interdepartmental Core	2	0-0-4	100	-	100
BIO 10203	Biophysical Chemistry	MDC**	3	3-1-0	50	50	100
CSP 10201	Computer Science II	MDC**	3	3-1-0	50	50	100
MAT 10203	Mathematical Methods II	MDC**	3	3-1-0	50	50	100
STA 10201	Probability and Distribution	MDC**	3	3-1-0	50	50	100

AEC – Ability enhancement Course; MDC – Multidisciplinary Course; VAC – Value Added Course; SEC – Skill Enhancement Course
Total Credits in Major (Chemistry) -14

- Student shall select any one language- Malayalam/Hindi/German
- * Will also be offered as an interdepartmental core/MDC
- ** Student shall select any one MDC

SEMESTER: 3

Semester Credit: 22 (Core: 19; Elective: 3) Cumulative Credit: 66

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10301	General Chemistry III	Core* (MDC)	3	3-1-0	50	50	100
CHE10302	Organic Qualitative Analysis Lab	Core*	2	0-0-4	100	-	100
CHE 10303	Chemical Kinetics and Surface Chemistry	Core	2	2-1-0	50	50	100
PHY 10301	General Physics III	Interdepartmental Core	3	3-1-0	50	50	100
PHY 10302	Physics Lab III (Electricity and Magnetism)	Interdepartmental Core	2	0-0-4	100	-	100
MAT 10301	Calculus III	Interdepartmental Core	3	3-1-0	50	50	100
YYY10301	Environmental Science	Interdepartmental Core (VAC 1)	4	4-1-0	50	50	100
BIO 10303	Human Disease and Health Care	MDC **	3	3-1-0	50	50	100
CSP 10301	Computer Science III	MDC**	3	3-1-0	50	50	100
MAT 10303	Matrix Theory and Graph Theory	MDC **	3	3-1-0	50	50	100
STA 10301	Statistical Inference	MDC **	3	3-1-0	50	50	100

AEC – Ability enhancement Course; MDC – Multidisciplinary Course; VAC – Value Added Course; SEC – Skill Enhancement Course

Total Credits in Major (Chemistry) -21

- Student shall select any one language- Malayalam/Hindi/German
- * Will also be offered as an interdepartmental core/MDC
- ** Student shall select any one MDC

SEMESTER: 4

Semester Credit: 23 (Core: 20, Elective: 3) Cumulative Credit: 89

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10401	Inorganic Chemistry 1 (Inorganic Main Group and Nuclear Chemistry)	Core	4	4-1-0	50	50	100
CHE10402	Organic Chemistry I Stereochemistry, Reaction Mechanism and Rearrangements	Core	4	4-1-0	50	50	100
CHE10403	Physical Chemistry I (Equilibrium and Introductory Statistical Thermodynamics)	Core	4	4-1-0	50	50	100
CHE10404	Theoretical Chemistry I (Introductory Quantum Mechanics)	Core	4	4-1-0	50	50	100
CHE10405	Inorganic Chemistry Lab I	Core	2	0-0-4	100	-	100
CHE10406	Physical Chemistry Lab 1	Core	2	0-0-4	100	-	100
Sxxxx	Skill Enhancement Course# (SEC 1)	Elective	3	0-0-3	100	-	100

Student shall select the course from a bouquet of courses offered by various departments

Total Credits in Major (Chemistry) -41

SEMESTER: 5

Semester Credit: 23 (Core: 16, Elective: 7), Cumulative Credit: 112

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10501	Inorganic Chemistry II (Coordination & Bioinorganic Chemistry and Polyhedral Boranes)	Core	4	4-1-0	50	50	100
CHE10502	Organic Chemistry II (Analytical and Spectroscopic Techniques in Organic Chemistry)	Core	4	4-1-0	50	50	100
CHE10503	Physical Chemistry II (Electrochemistry and Solid State Chemistry)	Core	4	4-1-0	50	50	100
CHE10504	Organic Chemistry Lab 1	Core	2	0-0-4	100	-	100
CHE10505	Inorganic Chemistry Lab 2	Core	2	0-0-4	100	-	100
CHE10506	Elective	Elective	4	4-1-0	50	50	100
Sxxxxxx	Skill Enhancement Course# (SEC 2)	Elective	3	0-0-3	100	-	100

Student shall select the course from a bouquet of courses offered by various departments

Total Credits in Major (Chemistry) - 57

SEMESTER: 6

Semester Credit: 23, (Core: 16, Elective: 7), Cumulative Credit: 135

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10601	Inorganic Chemistry III (Group Theory and Concepts in Inorganic Chemistry)	Core	4	4-1-0	50	50	100
CHE1602	Organic Chemistry III (Organic Chemistry Reactions, Reagents, Photochemistry & Pericyclic Reactions)	Core	4	4-1-0	50	50	100
CHE10603	Physical Chemistry III (Chemical Kinetics, Surface Chemistry and Catalysis)	Core	4	4-1-0	50	50	100
CHE10604	Organic Chemistry Lab 2	Core	2	0-0-4	100	-	100
CHE10605	Physical Chemistry Lab 2	Core	2	0-0-4	100	-	100
CHE10606	Elective	Elective	4	4-1-0	50	50	100
Sxxxxxx	Skill Enhancement Course# (SEC 3)	Elective	3	0-0-3	100	-	100

Exit with BSc Chemistry – Total Credit required - 135

Total Credits in Major (Chemistry) – 73 (54%)

SEMESTER: 7

Semester Credit: 22 (Core-18, Elective-4), Cumulative Credit: 157

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10701	Inorganic Chemistry IV (Reaction Mechanism and Organometallic Chemistry)	Core	4	4-1-0	50	50	100
CHE10702	Organic Chemistry IV (Natural Products, Dyes and Pigments)	Core	4	4-1-0	50	50	100
CHE10703	Theoretical Chemistry II (Approximations and Chemical Bonding)	Core	4	4-1-0	50	50	100
CHE10704	Spectroscopy	Core	4	4-1-0	50	50	100
CHE10705	Industrial Chemistry Lab	Core	2	0-0-4	100	-	100
CHE10706	Professional and Career Development in Chemistry	Audit	0	2-0-0	-	-	-
CHE10707	Elective	Elective	4	4-1-0	50	50	100

Total Credits in Major (Chemistry) -91

BSc Honors with Research

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
CHE10801	Elective	Elective (Online MOOC Course-SWAYAM, NPTEL, CUSAT)	4	4-1-0	50	50	100
CHE10802	Project	Core	16	-	-	300	100

Total Credits in Major (Chemistry) -107 (60%)

Exit with BSc Chemistry Honours (Research) – Total Credit required - 177

BSc Honors

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
CHE10801	Advanced Analytical and Instrumentation Techniques I	Core	4	4-1-0	50	50	100
CHE10802	Advanced Physical Chemistry	Core	4	4-1-0	50	50	100
CHE10803	Advanced Organic Chemistry	Core	4	4-1-0	50	50	100
CHE10804	Computational Chemistry Lab	Core	2	0-0-4	100	-	100
CHE10805	Open ended Lab	Core	2	0-0-4	100	-	100
CHE10806	Elective	Elective	4	4-1-0	50	50	100

Total Credits in Major (Chemistry) – 107 (60%)

Exit with BSc Chemistry Honours – Total Credit required - 177

SEMESTER: 9

Semester Credit: 20 (Core- 12, Elective-8), Cumulative Credit: 197

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10901	Advanced Analytical and Instrumentation Techniques II	Core	4	4-1-0	50	50	100
CHE10902	Instrumentation Lab	Core	4	0-0-8	0-	100	100
CHE10903	Mini Project	Core	4	0-0-8	-	100	100
CHE10904	Elective 1	Elective	4	4-1-0	50	50	100
CHE10906	Elective 2	Elective	4	4-1-0	50	50	100

Total Credits in Major (Chemistry) - 125

SEMESTER: 10

Semester Credit: 18 (Core: 18; Elective: 0) Cumulative Credit : 215

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 11001	Project Dissertation and Viva Voce	Core	16	-	-	300	300
CHE 11002	Course Viva	Core	2				

Total Credits in Major (Chemistry) – 141 (65%)

Total Credits Required for Integrated M. Sc. in Chemistry - 215

CHE 10101
GENERAL CHEMISTRY I

Credit 3 **54 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Appreciate the evolution of quantum mechanics and correlate the concepts to modern atomic structure.	Apply
C.O. 2: Analyze the structure and bonding in simple molecules by applying the concepts of MOT	Analyze
C.O. 3: Understand the different chemical bonding in organic molecules and reactive intermediates.	Understand
C.O. 4: Perform a statistical analysis of experimental data	Analyse

UNIT I	**10 hrs**
Atomic structure I - Blackbody emission and temperature, Photoelectric effect, Double slit experiment, Line spectrum of elements, Rutherford's experiment, Bohr's atomic model, Failure of Classical mechanics, Evolution of quantum mechanics - Heisenberg's uncertainty principle and its significance, wave particle duality, de Broglie equation.	
UNIT II	**10 hrs**
Atomic Structure -II - Quantum atomic model, hydrogen atomic orbitals and quantum numbers, atomic orbital equations (no derivation required), Sign of wave functions. Radial and angular wave functions. Radial and angular distribution curves. Shapes of s, p, d and f orbitals. Contour boundary and probability diagrams.	
UNIT III	**12 hrs**
Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Lande equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Solvation energy, Covalent bond, Valence Bond theory, Resonance and resonance energy, Molecular orbital theory. bonding, non- bonding, antibonding molecular orbitals (concept only) elementary pictorial approach of homo- and hetero-diatomic molecules H_2, B_2, C_2, O_2, N_2, CO, NO and CO_2, H_2O etc.	
UNIT IV	**10 hrs**
Localized and delocalized chemical bonding, the concept of aromaticity, writing proper Lewis	

structures, hybridization, reactive intermediates (carbynes, carbenes, carbocation, carbanion, radicals, arynes, nitrenes), Introduction to stereoisomerism. "Symbolism" in Organic Chemistry.	
UNIT V	**12 hrs**
Titrimetric analysis and calculations: Different types of titrations - neutralization, redox (permanganometry, dichrometry, iodometry, iodimetry), complexometric (EDTA titrations) and precipitation titrations – Principle of all types of titrations, titration curves, indicators. Significant figures, Accuracy, Precision, Error, Types of errors- Determinate and Indeterminate errors, Distribution of random errors, Mathematical Expression for error- Absolute and Relative error, Methods to reduce error, Statistical tools for expressing precision- Standard deviation, Relative standard deviation, Variance, Comparison of results- Students t test, f test, Criteria for rejecting a value-Q test, Confidence interval.	

Recommended Text Books:

1. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4th Ed., W.H. Freeman & Company, 2006.
2. Housecroft, C. and Sharpe, G., Inorganic Chemistry, 4th Edn., Pearson, 2012.
3. Atkins, P.W. and Paula, J. Physical Chemistry, 8th Edn., Oxford Press, 2006
4. Lee, J.D. Concise Inorganic Chemistry, 5th Edn., John Wiley & Sons, 1999.
5. Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of Inorganic Chemistry, 3rd Ed., Oxford, 1994.
6. Day, M.C. and Selbin,J. Theoretical Inorganic Chemistry, 2nd Edn., ACS Publications, 2002.
7. McMurry, J. Organic Chemistry, 5th Edn., Brooks/Cole, 2000.
8. Carroll, F.A. Perspectives on Structure and Mechanism in Organic Chemistry, 2nd Edn., Wiley, 2010.
9. March, J., Smith, D., March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 7th Edn., Wiley, 2013.
10. Skoog, West, Holler, Crouch, Fundamentals of Analytical Chemistry, Wiley, 9th Edn.
11. Fifield, F. W., Kealey, D., Principles and Practice of Analytical Chemistry, Academic Press, 5th Edn.
12. Robinson, J. W., Skelly Frame, E. M., Frame, G. M., II, Undergraduate Instrumental Analysis, Prentice Hall, 2009
13. Vogel's Textbook of Quantitative Chemical Analysis, 6th Edn, ELBS, 1998.

CHE 10102

QUANTITATIVE ANALYSIS LAB

Credit 2 **36 hours**

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

1. **Acidimetry and Alkalimetry:** Strong acid -Strong base, Strong acid-weak base, Weak acid-Strong base, Estimation of hardness of water.
2. **Redox Titrations:** Permanganometry- Estimation of oxalic acid, ferrous ion, MnO_2 in pyrolusite

Recommended Text Books:

1. Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearsons Education Ltd.

CHE 10103
CHEMISTRY IN EVERYDAY LIFE

Credits 2 **36 hours**

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Understand the importance and the role of chemistry in everyday life	Understand
C.O. 2: Learn about chemicals that lay the foundation for life	Understand
C.O. 3: Understand the type of chemicals used in house hold activities, cosmetics and medicine	Apply
C.O. 4: Apply knowledge of chemistry to improve quality of life	Apply

UNIT I	**6 hrs**
Molecules of Life - Cellular and chemical foundations of life, water unique properties, Carbohydrates and their sources, monosaccharides and disaccharides, examples, Lipids, Amino acids, Nucleic acids, Vitamins, Nutrients, Enzymes, Hemoglobin, structure and function, effect of CO, chlorophyll	
UNIT II	**8 hrs**
Chemistry for food: chemicals used in kitchen, Butter and edible oils, composition, importance, properties, saturated and unsaturated fatty acids, hydrogenated oils, milk and dairy products, chemistry of cooking, chemical and physical changes during cooking, microwave cooking, nutrients and their stability during cooking, food preservation, colouring and flavouring agents, Beverages, food adulteration, food poisoning	
UNIT III	**6 hrs**
Chemistry for cleaning: Soaps, chemical composition, preparation, cleaning action, synthetic detergents, bleaching, other house hold cleaning agents, tooth paste, mouth wash, sanitizers, shaving cream, shampoo disinfectants and antiseptics	
UNIT IV	**8 hrs**
Chemistry for cosmetics: Basic concepts-composition and classification, Skin chemistry, deodorants, antiperspirants, perfumes fragrances, effect of sunlight on skin, vitamin D, skin burns, sun screens, skin and hair care products, talcum powder, lipstick, moisturizers, colouring and bleaching agents, cosmetic formulations, baby care products.	
UNIT V	**8 hrs**

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

Recommended Text Books:

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

CHE 10201
GENERAL CHEMISTRY II

Credit 3 **54 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 based on their periodic classification	Understand
C.O. 2: Understand the basic concepts of aci-base theory and compare the strength of various acids and bases	Apply
C.O.3: Assign the nomenclature of simple organic molecules following IUPAC rules and identify various functional groups in organic chemistry	Understand
C.O.4: Differentiate the properties of real gases from those of a perfect gas	Analyse
C.O.5: Predict changes in thermodynamic parameters during a process and predict the spontaneity.	Apply

UNIT I	**10 hrs**
Periodic Properties: Atomic weights, Development of periodic law, The modern periodic table, Basis of periodic classification, orbital types and periodic table, Commonality in electronic configurations, Atomic sizes, ionization energy, Electron negativity, Electron Affinity, Polarizability and polarizing power, Relative orbital energies and overlap, Trends associated with properties – Physical and chemical, Anomalies in periodic properties.	
UNIT II	**12 hrs**
Acid Base concepts: Theories of acids and bases- Arrhenius Theory, Bronsted-Lowry definition, pH, PKa , PKb, Lux Flood Definition, Solvent system definition, Lewis Definition, Usanovich Definition, Generalized concept. Ionic product of water, Common ion effect, Solubility product, Acid strength, Degree of hydrolysis of salts, Buffer solutions, Mechanism of buffer action, Henderson equation.	
UNIT III	**10 hrs**
Nomenclature and functional groups in organic molecules: Rules of IUPAC system of nomenclature, naming of common organic compounds. Introduction to organic functional groups- alcohols, ethers, halides, amines, nitro compounds,	

nitriles, aldehydes, ketones, carboxylic acids and derivatives.	
UNIT IV	**10 hrs**
Gaseous State: Kinetic Theory of gases, Maxwell Boltzmann distribution of molecular velocities (Qualitative approach), Different types of velocities, Gas Laws, Ideal gas equation, Real gases- Deviation from ideal behavior- Compressibility factor, Van der Waals equation, Virial equation, PV isotherms, Continuity of states, Law of corresponding states, Critical phenomena and critical constants. Transport properties.	
UNIT V	**12 hrs**
Thermodynamics: State functions, Reversible and irreversible processes, Isothermal and adiabatic processes, Concepts of work, heat, Internal energy, enthalpy, Heat capacity, entropy, Gibbs energy, Helmholtz energy, Work done in isothermal and adiabatic reversible and irreversible processes, First, second and third laws of thermodynamics, Entropy and free energy as criteria for spontaneity and equilibrium, Unattainability of absolute zero. Standard states. Entropy and free energy changes during isothermal and adiabatic processes, Changes in entropy and free energy with Temperature and pressure, Gibbs Helmholtz equation, Maxwells relations, Joule Thomson effect- Inversion temperature, Application of J.T effect - Liquefaction of gases.	

Recommended Text Books:

1. Mingos, D. M. P., Essential trends in inorganic chemistry, Oxford University press, 1998.
2. Wulfsberg, G., Inorganic Chemistry, VIVA, 2002.
3. Greenwood, N. N., Earnshaw, A., Chemistry of Elements, Maxwell Macmillan, International Edition, Pergamon Press, 1989.
4. Cotton, F.A., Wilkinson, G, Advanced Inorganic Chemistry. Wiley-VCH, 1999.
5. Huheey, J. E., Keiter, E. A., Kieter, R. L., Medhi, O. K., Inorganic Chemistry Principles, Structure and Reactivity, Pearson Education, 4 th edition, 2009.
6. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4 th Ed., W.H.Freeman & Company, 2006.
7. F. Daniels and R. A. Alberty, Physical Chemistry, Wiley Publishers, 4 th Edn 2004
8. J. G. Smith, Organic Chemistry, 3rd edn., 2011.
9. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd edn., Oxford, University Press, 2012.
10. P.W Atkins, Julio De Paula, Physical Chemistry, Oxford University Press, 10th/11th edn, 2017/2018.
11. Ira.N.Levine, Physical Chemistry, Tata Mc Graw Hill, 6th edn (Indian) 2011.
12. R.A.Alberty & R.J.Silbey, Physical Chemistry, Wiley Publishers, 4th edn, 2004.
13. T. Engel and P. Reid, Physical Chemistry, Pearson, 3rd Edn, 2013.
14. K J Laidler, J.H Meiser, Physical Chemistry, 4th edn 2003.

CHE 10202

INORGANIC QUALITATIVE ANALYSIS LAB

Credit 2 **36 hours**

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

Systematic qualitative analysis of mixtures containing two acid and two basic radicals from the list given below by semi micro method

Pb^{2+}, Cu^{2+}, Bi^{2+}, Cd^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mg^{2+}, NH_4^{+}, CO_3^{2-}, SO_4^{2-}, NO_3^{-}, F^{-}, Cl^{-}, $C_2O_4^{2-}$, CH_3COO^{-}, PO_4^{3-}.

Recommended Text Books:

1. A.I. Vogel, A Text Book of Qualitative Inorganic Analysis, Longman, 1966.

CHE10203

INDUSTRIAL APPLICATIONS OF PETROCHEMICALS AND PETROLEUM PRODUCTS

Credit 2 **36 hours**

Course Outcome After the completion of the course, the student will be able to	Cognitive level
C.O. 1: Explain the chemistry and application of the basic building block chemicals derived from fossil sources.	Understand
C.O. 2: Discuss methods of synthesis and the environmental impact of industrial polymers	Understand

UNIT I	**6 hrs**
Chemistry, use, and the environmental and economic impact of basic building block chemicals derived from fossil sources such as petroleum and coal. Fermentation industry. Introduction to unit processes and operations.	
UNIT II	**8 hrs**
Petroleum refining and important petrochemicals. Ethylene, acetylene, propylene, butadiene and butenes, aromatic hydrocarbons (benzene, toluene, xylenes-BTX), methane and other alkanes cracking and reforming processes	
UNIT III	**8 hrs**
Chemicals from C2, C3 and C4 streams: Chemicals from Propylene. Polymerization to polypropylene, addition reactions, conversion to acrolein and acrylonitrile, cumene hydroperoxide, phenol and acetone. Butadiene-polymerization, Diels-Alder reaction, 1,4-additions, adiponitrile and hexamethylenediamine for nylon production.	
UNIT IV	**8 hrs**
Chemicals from BTX stream: Chemicals from Benzene, Toluene and Xylene (BTX Process)- Review of electrophilic substitution reactions, phenol-formaldehyde resins, reduction of benzene to cyclohexane, oxidation to adipic acid (nylon 6,6 and nylon 6), caprolactam from cyclohexanone oxime, Beckmann rearrangement, reactions of toluene, benzyl chloride, benzoic acid, benzaldehyde, xylene to phthalic anhydride (plasticizers).	
UNIT V	**6 hrs**
General introduction to synthetic high polymers- inputs and methods of polymerization. Resins, plastics and elastomers.	

Recommended Text Books:

1. Szmant, H.H. "Organic Building Blocks of the Chemical Industry", Wiley & Sons, 1989
2. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2^{nd} edn., Oxford University Press, 2012.
3. Speight, James G. Handbook of Petroleum Refining. CRC press, 2016.
4. M. Sami, L. F. Hatch. Chemistry of Petrochemical Processes. 2^{nd} edn., Elsevier, 2001.
5. V.R. Gowariker, N.V. Viswanathan, J. Sreedhar, Polymer Science, New Age International, 2011.
6. F.W. Billmeyer Jr., Text book of Polymer Science, 3^{rd} edn., John Wiley & Sons, 1984.

CHE 10301
GENERAL CHEMISTRY III

Credit 3 **54 hours**

Course Outcome After the completion of the course, the student will be able to	**Cognitive level**
C.O. 1: Apply the basic concepts of kinetics to various processes/reactions	Apply
C.O. 2: Understand the basic surface phenomena and extended application to adsorption.	Apply
C.O. 3: Develop an insight into the importance of organic chemistry in life.	Understand
C.O. 4: Describe the different types of organic reactions.	Understand

UNIT I	**9 hrs**
Chemical Kinetics: Rate laws, Order and molecularity, Zero, first, second and third order reactions- Integration of rate equations, Half-life period, Arrhenius equation.	
UNIT II	**9 hrs**
Adsorption: Physical and chemical adsorption, adsorption isotherms- Langmuir (kinetic derivation), Freundlich and BET (No derivation) isotherms, Determination of surface area using Langmuir and BET isotherms, Catalysis- Homogeneous and heterogeneous, Enzyme catalysis.	
UNIT III	**10 hrs**
Stereochemistry: Configuration and conformation- Concept of configuration, classification of stereoisomers, optical isomerism, chirality, wedge formula, Fischer projection, Newman projection, perspective formula. Relative and absolute configurations, sequence rules, D & L, R & S systems of nomenclature. Enantiomers, meso form, diastereoisomers, epimers, anomers. Geometrical Isomerism: E-Z notation. Conformational analysis: Strain in molecules, acyclic molecules, cyclohexane, substituted cyclohexanes- A values.	
UNIT IV	**12 hrs**
Basics of reaction mechanism: 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. Nucleophilic substitutions - S_N1, S_N2, substitutions on aromatic carbon, Addition reactions - polar and nonpolar addition - addition of Bromine and hydrogen halides to double bonds - Markownikoff's rule and peroxide effect., Elimination - E1, E2, E1CB, pyrolytic elimination.	

UNIT V	14 hrs
Biomolecules (structure and function): General introduction to carbohydrates, ring-chain tautomerism, glycocidic linkage, classification, monosaccharides, disaccharides, oligosaccharides, polysaccharides, reducing and nonreducing sugars, structure of aldohexoses, fructose and ribose, "sugar-like" artificial sweetners, basic introduction to amino acids, proteins and nucleic acids.	

Recommended Text Books:

1. P.W Atkins, Julio De Paula, Physical Chemistry, Oxford University Press, 10th/11th edn, 2017/2018.
2. Ira.N.Levine, Physical Chemistry, Tata Mc Graw Hill, 6th edn (Indian) 2011.
3. R.A.Alberty & R.J.Silbey, Physical Chemistry, Wiley Publishers, 4th edn, 2004.
4. T. Engel and P. Reid, Physical Chemistry, Pearson, 3rd Edn, 2013.
5. K J Laidler, J.H Meiser, Physical Chemistry, 4th edn 2003.
6. 1. Clayden J., Greeves, N. Warren, S., Organic Chemistry, 2nd edn. Oxford University Press, 2001.
7. Bruice, P.Y. Organic Chemistry, 7th edn., Prentice Hall Inc., 2013.
8. March, J., Smith, D., March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 7th edn., Wiley, 2013.
9. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th edn., Springer, 2008.
10. J. McMurry, Organic Chemistry, 5th edn., Brooks/Cole, 2000.
11. P. Sykes, Guidebook to Mechanism in Organic Chemistry, 6th edn., Prentice Hall, 1986.

CHE 10302

ORGANIC QUALITATIVE ANALYSIS LAB

Credit 2 **36 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 group analysis and prepare the corresponding derivative	Analysis

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 of Organic Chemistry, 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

CHE 10303
CHEMICAL KINETICS AND SURFACE CHEMISTRY

Credit 2 **36 hours**

Course Outcome After the completion of the course, the student will be able to	**Cognitive level**
C.O. 1: Apply the laws of chemical kinetics and photochemistry to calculate rate/ rate constants/quantum yield of different types of reactions.	Apply
C.O. 2: Apply theory of reaction rates to chemical reactions/processes	Apply
C.O. 3: Understand the surface properties and applications of interfaces.	Apply

UNIT I	**8 hrs**
Complex Reactions -Consecutive, Parallel and Opposing reactions (elementary concepts), Steady state approximation. Chain reactions, Branched chain reactions (basic concepts)	
UNIT II	**8 hrs**
Theories of Reaction rate- Collision Theory, Transition state theory (elementary concepts), Unimolecular reactions- Lindemann mechanism.	
UNIT III	**6 hrs**
Photochemistry: Photochemical laws, Beer-Lambert Law, Quantum yield, Photophysical and photochemical processes- Jablonski Diagram, Fluorescence, Phosphorescence-, Chemiluminescence, Bioluminescence, Photosensitisation.	
UNIT IV	**6 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.	
UNIT V	**8 hrs**
Colloids: Lyophilic and Lyophobic colloids, Preparation of colloids, Kinetic, optical and electrical properties, Electrical double layer Models for double layer: Helmholtz, Gouy- Chapman and Stern models, Zeta potential. Stability of colloids, Protective colloids- Gold number, Flocculation, Hardy Schulze rule, Surfactants, micelles, Donnan membrane equilibrium, Dorn effect, Sedimentation potential and streaming potential, Emulsions, Gels, Sols.	

Recommended Text Books:

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

CHE 10401
INORGANIC CHEMISTRY I
(Inorganic Main Group and Nuclear Chemistry)

Credit 4 **72 hrs.**

Course Outcome After completion of the full course the student should be able to	Cognitive level
C.O. 1: Interpret the types of bonding and structure based on the electronic configuration	Apply
C.O. 2: Explain the reactivity and physicochemical properties based on the type of bonding	Analyse
C.O.3: Explain the properties of transition metals and lanthanides	Apply
C.O. 4: Compare the structure, bonding and reactivity of the compounds of main group elements	Analyse
C.O. 5: Describe the radioactivity phenomena and its applications	Apply

UNIT I	**12 hrs**
s- Block elements- Hydrogen, Hydrogen Bonding, Hydrates, Hydrogen ions, acids and bases, Group 1 elements - General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Flame colors and spectra, Color of compounds, Alkali metals in liquid ammonia and other solvents, Oxides, hydroxides, hydrides, alkoxides, amido complexes, Ionic salts and M^+ ions in solution, Alkali metal complexes, Organolithium compounds.	
UNIT II	**12 hrs**
Group 2 elements – General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Elemental Beryllium, Binary Compounds, Coordination compounds with oxygen and nitrogen ligand, organoberyllium compounds, Compounds of Magnesium, Calcium, Strontium-oxides, halides, hydrides, carbides, ionic salts and complexes, alkoxides. Grignard reagents – preparation and properties	
UNIT III	**18 hrs**
General periodic trends of d and f block elements, Metallic property, Chemistry of variable oxidation states, properties of d configuration - d^0 to d^{10}, Type of compounds. physical and chemical properties of transition elements; Difference between first row and other rows, Double salts and coordination compounds. Introduction to coordination compounds; coordination numbers and geometries in transition metal	

complexes; nomenclature; isomerism in transition metal complexes – structural, geometrical and optical isomerism. Lanthanides and Actinides- Stable oxidation states, lanthanide and actinide contraction, Occurrence and recovery; Separation of Lanthanides; difference between 4f and 5f orbitals, Industrial importance of lanthanides. Actinides: Comparison with lanthanides and general characteristics	
UNIT IV	**16 hrs**
Types of oxides, Chemical properties of Dioxygen, Singlet oxygen, ozone, Peroxo compounds, Superoxide. Nitrogen compounds- Nitrides, Ammonia, Hydrazine, Oxides of Nitrogen, Oxo acids and anions. Sulphur-Nitrogen compounds: Tetrasulphur tetranitride, disulphur dinitride and polythiazyl. SxNy compounds. S-N cations and anions. Sulphur-phosphorus compounds: Molecular sulphides such as P_4S_3, P_4S_7, P_4S_9 and P_4S_{10}. Phosphorus-nitrogen compounds: Phosphazenes and poly phosphazenes. Interhalogen compounds, Structure, hybridization and reactivity of ClF_3, ICl_3, IF_5 and IF_7, Compounds of Xe, Kr and Rn	
UNIT V	**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. Radio carbon dating principles.	

Recommended Text Books:

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

CHE10402
ORGANIC CHEMISTRY I
(Stereochemistry, Reaction Mechanism and Rearrangements)

Credit 4 **72 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Apply the concepts of isomerism and analyse the conformation and configuration of organic molecules.	Apply
C.O. 2: Illustrate the mechanism involved in various reactions	Apply
C.O. 3: Describe bonding properties in organic molecules	Understand
C.O. 4: Illustrate the mechanistic pathway of different rearrangement reactions and identify the products.	Apply
C.O. 5: Predict the reactivity of an organic compound based on its structure and the reaction conditions.	Apply

UNIT I	**16 hrs**
Stereochemistry: Geometrical & Optical isomerism: the origin of chirality, chiral centres and configuration, axes and planes, helicity. Prochiral centres and faces. Topicity relationships, enantiotopic and diastereotopic groups and faces. Symmetry, stereochemistry and time scale. Allenes, cumulenes, biphenyls, and spirans. Compounds containing chiral atoms other than carbon. Strain, types of strain including B, F, I, Pitzer strain and Baeyer strain. Acyclic sp^3–sp^3, sp^3-sp^2 systems, structure and stability of small, medium, and large rings, cyclohexane, substituted cyclohexanes, cyclohexenes, decalins, and bicyclic systems.	
UNIT II	**16 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 III	**12 hrs**
Substitutions on Aliphatic carbon: –saturated and unsaturated systems – Mechanism of nucleophilic substitution – S_N2, S_N1 – ion pairs, SET, Neighbouring group participation – non classical carbocations, SNi, Tetrahedral mechanism. Electrophilic substitution – SE2, SEi, SE1. Free radical substitution. Reactivity – Effect of substrate structure, nature of reagents, solvents and stereochemistry on the outcome of these reactions. Ambident nucleophiles and substrates. Typical reactions involving substitution. Substitutions on aromatic carbon: Mechanism of electrophilic, nucleophilic and free radical substitutions – orientation and reactivity. Typical reactions involving aromatic substitution.	
UNIT IV	**14 hrs**
Additions and eliminations : Mechanisms of polar addition – electrophilic, nucleophilic and free radical addition. Nonpolar additions (excluding pericyclic reactions) - Reactivity and orientation. Eliminations - E2, E1 and E1CB mechanisms, reactivity and orientation. Pyrolytic syn eliminations, α - eliminations, elimination *vs* substitution. Typical reactions involving addition and elimination.	
UNIT V	**14 hrs**
Rearrangements: Wagner-Meerwein, Pinacol, Demyanov, dienone-phenol, Favorskii, Wolff, Hofmann, Curtius, Lossen, Schmidt, Beckmann, benzidine, and Hofmann-Loffler, Fries, Baeyer-Villiger rearrangements. Fritsch-Buttenberg-Wiechell rearrangement, Corey-Fuchs reaction, Wittig rearrangement.	

Recommended Text Books:

1. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
2. March, J., Smith, D., March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 7th ed., Wiley, 2013.
3. Bruice, P.Y. Organic Chemistry, 7th ed., Prentice Hall Inc., 2013.
4. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
5. J. McMurry, Organic Chemistry, 5th ed., Brooks/Cole, 2000.
6. P. Sykes, Guidebook to Mechanism in Organic Chemistry, 6th ed., Prentice Hall, 1986.
7. E. L. Eliel and S. H. Wilen, Stereochemistry in Organic Compounds, John Wiley, 1994.
8. P. S. Kalsi, Stereochemistry, Conformation and Mechanism, 10th ed., New Age Publications, 2019.
9. E. V. Anslyn, D. A. Dougherty, Modern Physical Organic Chemistry. University Science Books, 2006.
10. Bruckner, R. Advanced Organic Chemistry: Reaction Mechanisms, 1st edn., Academic Press, 2001.

CHE 10403
PHYSICAL CHEMISTRY I
(Equilibrium and Statistical Thermodynamics)

Credit 4 **72 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Predict the dependence of physical and chemical equilibrium on pressure, temperature and concentration.	Apply
C.O. 2: Describe the significance of chemical potential in physical and chemical processes	Apply
C.O. 3: Understand the thermodynamics of phase transitions and interpret the phase diagram of a given system.	Analyse
C.O. 4: Apply the principles of statistical thermodynamics to ideal gases, solids and metals.	Apply

UNIT I **14 hrs**
Thermochemistry- Enthalpy of physical and chemical changes, Temperature dependence of reaction enthalpies, Hess's law Chemical Equilibria: Chemical Equilibria and free energy, Equilibrium Constant, Applications of free energy function to physical and chemical changes- Le Chateliers Principle. Effect of temperature and pressure on the chemical equilibrium- van't Hoff reaction isotherm and isochore.
UNIT II **14 hrs**
Physical Transformation of substances: Molar Gibbs energy, Phase stability and transitions, phase equilibria of pure substances, Clausius Clapeyron equation, Solid-liquid, liquid-vapor and solid-vapor equilibria, phase rule, phase diagrams of one-component systems, Ehrenfest Classification of Phase transitions.
UNIT III **14 hrs**
Thermodynamics of Mixtures: Partial molar quantities, Chemical potential, Thermodynamics of mixing, Excess function, Chemical potential of liquids, Gibbs Duhem Equation and Duhem Margules Equation. Ideal solutions, Deviations from ideality, Concepts of fugacity and activity, Ideal dilute solutions, Henry's and Raoult's laws, Colligative properties, Regular solutions.
UNIT IV **14 hrs**
Phase Equilibria of Binary and ternary Systems: Vapor pressure-composition diagrams, Temperature-

composition diagrams, Liquid-liquid systems – Completely miscible, Partially miscible and Immiscible, Azeotropes and Azeotropic distillation, Steam distillation. Solid-Liquid systems, Solid-vapour systems. Three-component systems.	
UNIT V	**16 hrs**
Thermodynamic probability, microstate and macrostate, entropy and probability, most probable distribution, residual entropy and its calculation. Ensembles, Maxwell - Boltzman statistics. Quantum statistics: Bose - Einstein statistics, Fermi - Dirac statistics, Comparison of Maxell - Boltzman, Bose- Einstein and Fermi - Dirac Statistics, Dilute Systems. Partition function and its relation to thermodynamic properties: Translational, rotational and Vibrational partition function. Molecular partition function for delocalized systems, calculation of equilibrium constant using partition functions. Heat capacity of gases and solids	

Recommended Text Books:

1. P.W Atkins, Julio De Paula, Physical Chemistry, Oxford University Press, 10th/11th Edn, 2017/2018.
2. Ira.N.Levine, Physical Chemistry, Tata Mc Graw Hill, 6th Edn (Indian) 2011.
3. R.A.Alberty & R.J.Silbey, Physical Chemistry, Wiley Publishers, 4th Edn, 2004.
4. T. Engel and P. Reid, Physical Chemistry, Pearson, 3rd Edn, 2013.
5. K J Laidler, J.H Meiser, Physical Chemistry, 4th Edn 2003.
6. D.A McQuarrie, J.D Simon, Molecular Thermodynamics, Viva Student Edn. 2010.
7. L. K. Nash, Elements of Chemical Thermodynamics, Addison Wesley, 2nd Edn, 2013.
8. F.W Sears, Introductions to Thermodynamics, Kinetic Theory of Gases and Statistical Mechanics, Addision Wesley Pub. Cambridge, 1998.
9. F.C. Andrews, Equilibrium to Statistical Mechanics, John Wiley, New York, 2002.
10. L.K. Nash, Statistical Thermodynamics, Addison Wesley, New York, 1999.
11. D. A. McQuarrie, Physical Chemistry- A Molecular Approach, South Asian Edn., 2008.
12. D. A. McQuarrie, Statistical Thermodynamics, South Asian Edn., 2008.
13. M. Dole, Introduction to Statistical Thermodynamics, Prentice Hall, London, 1997.

CHE 10404
THEORETICAL CHEMISTRY – 1
(Introductory Quantum Mechanics)

Credit 4 **72 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Describe and justify the importance of Quantum Mechanics	Analyse
C.O. 2: Understand and apply various postulates in deriving property operators and Schrodinger equation	Apply
C.O. 3: Apply the postulates of quantum mechanics to simple systems of chemical interest, such as the particle-in-a-box, harmonic oscillator, and rigid rotor.	Analyse
C.O. 4: Interpret the solutions and appreciate the quantization concept	Analyse

UNIT I	**18 hrs**
Basics: Evolution of quantum mechanics, Heisenberg's matrix mechanics- commutator relationships, position representation, coordinate- Cartesian, cylindrical and spherical polar and their interconversion, Complex number and their representation in various coordinate systems. Operators, Algebra of operators, Linear and Hermitian operators, Eigenvalue equation, Significance, well-behaved functions, Time dependent Schrodinger equation, conservative and non-conservative systems	
UNIT II	**12 hrs**
Solving the Schrodinger equation-Particle in a box: Quantum mechanical postulates, construction of various operators – kinetic energy, angular momentum. Translational motion- free particle, particle in one, two and three-dimensional box (rectangular and cubical), separation of variables, concept of degeneracy, introduction to quantum mechanical tunneling.	
UNIT III	**14 hrs**
Solving the Schrodinger equation-Simple Harmonic oscillator: Vibrational motion, 1-D Harmonic oscillator, Method of power series, Hermite equation and Hermite Polynomials, Recursion formula, wave function and energy. Transition moment integral, selection rules, Extension of the results to 3D-SHO.	
UNIT IV	**10 hrs**
Solving the Schrodinger equation-Planar Rigid Rotor: Rigid rotator, Conversion of laplacian opertor into spherical polar coordinates, Particle on a ring, phi equation, Angular momentum operator L^2 and Lz,	

quantization, polar plots	
UNIT V	**18 hrs**
Solving the Schrodinger equation-Non-planar RR: Theta equation and solutions Lagendre equation and Lagendre polynomials, Restriction of m_l values, Spherical harmonics, Angular momentum operator L^2 and Lz, Space quantization, polar plots of spherical harmonics.	

Recommended Text Books:

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

CHE 10405
INORGANIC CHEMISTRY LAB 1

Credit 2 **36 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 by complexometric reactions	Apply
C.O. 2: Identify the cation from the given mixture	Apply

Complexometry: Estimation of Zinc, Magnesium, Calcium, Determination of hardness of water, Estimation of different metal ions from a mixture – use of masking agents

Analysis of less common ions: 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. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6^{th} Edn., Pearson Education, Noida, 2013.
2. A.I. Vogel, G. Svehla, Vogel's Qualitative Inorganic Analysis, 7^{th} edition., Longman, 1996.
3. V.V. Ramanujam, Inorganic Semimicro Qualitative Analysis, The National Pub.Co., 1974.

CHE 10406
PHYSICAL CHEMISTRY LAB -I

Credit 2 **36 hours**

Course Outcome	**Cognitive level**
After the completion of the course the student will be able to execute and perform experiments based on thermodynamic and kinetic principles	Evaluate

Chemical Kinetics: Determination of rate constant of acid hydrolysis of ester. Determination of kinetic parameters.

Phase diagrams:

CST: Phenol-water system, Determination of CST, Analyse the effect of KCl and succinic acid on CST.

Solid-Liquid Equilibria: Simple Eutectic systems- Construction of phase diagrams, Determination of Molal Depression constant of a solvent and molecular weight of solute by Rast method.

Transition temperature: Determination of transition temperature of a salt hydrate-water system and molecular weight of a solute

Three component systems: Construction of phase diagram.

Adsorption: Verification of the validity of Langmuir and Freundlich adsorption isotherms.

Recommended Text Books:

1. J. N. Gurtu, and A. Gurtu Advanced Physical Chemistry Experiments, 6th Edn., Pragati Prakashan, 2014.
2. J. B. Yadav, Advanced Practical Physical Chemistry, 36th Ed., 2016.
3. D.P Shoemaker, G.W Garland, J.W Nibler, Experiments in Physical Chemistry, 5th Edn. McGraw Hill.

CHE 10501

INORGANIC CHEMISTRY-II

(Coordination & Bioinorganic Chemistry and Polyhedral Boranes)

Credit 4 **72 hours.**

Course Outcome After completion of the full course the student should be able to	**Cognitive level**
C.O. 1: Describe and explain the structure, bonding and magnetism of metal complexes using CFT.	Analyse
C.O. 2: Describe the metal-ligand interactions in terms of sigma and pi bonding and covalency using LFT and MO theory	Evaluate
C.O. 3: Understand the importance of metal ions in living systems	Analyse
C.O. 4: Predict the stability and topology of different polyhedral boranes and related compounds.	Analyse

UNIT I	**12 hrs**
Werner's theory, Effective atomic number, Bonding in coordination compounds. Valence bond description and its limitations. valence bond theory (inner and outer orbital complexes). Crystal Field Theory (CFT). d-orbital splitting in octahedral and tetrahedral geometries, measurement of 10 Dq (Δ_o), crystal field stabilization energy, CFSE in weak and strong fields, effect of pairing energy, factors affecting the crystal-field parameters. Crystal field splitting of square planar, trigonal bipyramidal, trigonal planar and linear geometries,	
UNIT II	**12 hrs**
Application of crystal filed theory, colour and spectral behaviours. magnetism of first-row transition metal complexes, lattice energies, ionic radii, site preferences in spinels. Spectrochemical series, Demerits of CFT. Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, Jahn – Teller effect in octahedral and tetrahedral complexes, square planar geometry. Stabilization of unusually low and high oxidation states of metals.	
UNIT III	**16 hrs**
Molecular Orbital Theory: construction of molecular orbital diagrams (using group theory-qualitative idea only), qualitative MO diagrams for octahedral, tetrahedral and square planar complexes, effect of π-bonding, experimental evidence for π-bonding, spectrochemical series. Ligand field theory, Effect of π-donor and π-acceptor ligands in LFSE, back bonding.	
UNIT IV	**14 hrs**

Metal ions in biological systems - Biochemistry of iron – Haemoglobin and myoglobin - O_2 and CO_2 transportation (Elementary idea of structure and oxygen binding), Structure and mechanism of action of sodium potassium pump - Biochemistry of Ca, Zn and Co – Toxicity of metal ions (Pb, Hg and As). Anticancer drugs: *Cis*-platin, oxaliplatin and carboplatin– Structure and significance. Non-Heme Iron Proteins: Iron storage and transfer – ferritin, transferrin; electron transfer (Iron-sulfur protein) – rubredoxin, ferredoxin; O_2 transport – hemerythrin Copper proteins and Enzymes–Hemocyanin, superoxide dismutase, ceruloplasmin, cytochrome C oxidase; Zinc and Cobalt enzymes carbonic anhydrase, carboxypeptidase, interchangeability of zinc and cobalt enzymes; Vitamin B12; Photosynthesis and N_2 fixation
UNIT V **18 hrs**
Electronic structure and allotropes of boron, boron halides, boron heterocycles, borazine Structure and bonding in polyhedral boranes and carboranes, styx notation; electron count in polyhedral boranes; Wade's rule; topological approach to boron hydride structure. Importance of icosahedral framework of boron atoms in boron chemistry. Closo, nido and arachno structures. Synthesis of polyhedral boranes; electron counting in polycondensed polyhedral boranes, mno rule. Carboranes, metallocarboranes.

Recommended Text Books:

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

CHE 10502
ORGANIC CHEMISTRY II
(Analytical and Spectroscopic Techniques in Organic Chemistry)

Credit 4 **72 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Apply the principles of separation, purification and chromatographic techniques in organic synthesis.	Apply
C.O. 2: Explain the basic principle of spectroscopy in particular IR, Raman, UV-Visible and NMR spectroscopy.	Understand
C.O. 3: Identify structures of simple organic compounds based on the data from UV-Vis, IR, Mass Spectrometry, ^{1}H NMR and ^{13}C NMR spectroscopy.	Apply

UNIT I	**14 hrs**
Introduction to GLP and lab safety, Cooling mixtures, Separation and Purification Techniques: Recrystallization, use of drying agents, sublimation. General principles of distillation, fractional distillation, steam distillation, and distillation under reduced pressure. Solvent extraction. Chromatographic Techniques: Chromatography - Principle of differential migration. Classification of chromatographic methods. Basic principle and uses of Thin layer chromatography (TLC), Paper chromatography (PC), R_f value, Column chromatography, Gas chromatography (GC), High-performance Liquid chromatography (HPLC), Size exclusion chromatography.	
UNIT II	**14 hrs**
Nature of electromagnetic radiation, its interaction with matter, intensity and width of spectral lines, Classical and quantum chemical approach to absorption of radiation by molecules. Energy levels in molecules. UV-visible Spectroscopy: Types of electronic transitions, Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; Effect of structure on absorption characteristics, Application of Woodward Rules for calculation of λmax for the following systems: α,β-unsaturated aldehydes and ketones, λmax for polyenes, aromatic aldehydes, ketones, esters. IR spectroscopy: Fundamental and non-fundamental molecular vibrations; IR absorption positions of O and N containing functional groups; Effect of H-bonding, concentration, temperature, conjugation, resonance and ring size on IR absorptions; Fingerprint region and its significance; application in	

functional group analysis. Fourier transform IR, group frequencies, fundamental frequencies and overtones, combination tones, Fermi Resonance. Basic introduction to Raman spectroscopy.	
UNIT III	**16 hrs**
NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift and factors influencing it; Spin–Spin coupling and coupling constant; Anisotropic effects in alkene, alkyne, aldehydes and aromatics, Interpretation of NMR spectra of simple compounds. Proton decoupled Carbon-13 NMR, introduction to polarization transfer and NOE.	
UNIT IV	**12 hrs**
Mass spectrometry – Introduction. EI ionization. Fragmentation modes and determination of molecular mass by MS. Soft ionization techniques, ion separation and analysis, and hyphenated techniques. HRMS and molecular formula.	
UNIT V	**16 hrs**
Problems based on the combined application of various spectroscopic techniques.	

Recommended Text Books:

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

CHE 10503
PHYSICAL CHEMISTRY II
(Electrochemistry and Solid State Chemistry)

Credit 4 **72 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Describe the theories and mechanism of ionic and electronic conductance and apply the concepts.	Apply
C.O. 2: Explain the basic theory of electroanalytical techniques.	Apply
C.O. 3: Understand basic properties and symmetry of solids	Understand

UNIT I	**14 hrs**
Introduction- Electrochemical Cells, Electrodes, Types of electrodes- Standard hydrogen electrode, Calomel electrode, Quinhydrone electrode. Electrolytes, Half Reactions, Electrochemical Work, Electrodics: Equilibrium electrochemistry- Half- reactions and electrodes, Standard Electrode potential, Nernst Equation. EMF and free energy. Types of cells. Electrochemical series. Liquid junction potential. Ion–Solvent, Ion–Ion Interactions, Ionic and Electronic Conductance, Conductance Measurement, Equivalent Conductance, Kohlrausch's Law, Ostwalds dilution law, Ionic Mobility, Walden's rule, abnormal conductance, Transport Number- Factors Influencing, measurement- Hittorf's and moving boundary methods.	
UNIT II	**16 hrs**
Electrode–Ion interface, liquid junction potential, Electrical Double Layer, Electrode and Electrolyte polarization. Overpotential. Butler Volmer Equation. Tafel Plot. Mass transfer control, Charge transfer at electrode-electrolyte interface. Double layer. Electrocapillarity. Hydrogen and Oxygen overvoltage. Activity and Activity co-efficients, Debye-Huckel Theory, Limitations. Extension, Bjerrum ion pair formation. Ionic Atmosphere, Relaxation, Mechanism of Electrolytic Conductance, Debye Huckel Onsager equation for strong electrolytes.	
UNIT III	**12 hrs**
The electromotive force, Standard potentials, Applications of standard potentials, Determination of solubility product and activity co-efficient, Activity and Activity Coefficient of Electrolytes. Corrosion of metals- different forms of corrosion and prevention. Electrochemical Theory of	

corrosion – methods of prevention. Porbaux and Evans diagram. Fuel Cell, Batteries: Basic theory and types (Elementary idea)
UNIT IV **14 hrs**
Electroanalytical Techniques: pH determination, Redox indicators principle. Conductometric and potentiometric titrations. Cyclic voltammetry, Square wave, and linear sweep voltammetry, Chronoamperometry, Chronopotentiometry, Impedance. Coulometry and Polarography, Spectroelectrochemistry (Basic Principles)
UNIT V **16 hrs**
Crystal structures and symmetry, Crystallographic point groups, space group, unit cells, Miller indices, Seven crystal systems and Bravais lattices, Simple, body centered and face centered systems, Packing in solids- packing diagrams, close packing,- hcp and ccp structures, XRD, Braggs equation – derivation, Powder and rotating crystal technique. Identification of cubic crystals based on interplanar ratio. Ionic solids with formula MX (CsCl, NaCl, Zinc Blende and Wurtzite Structures), MX2 (Fluorite and Antfluorite Structures, Cadmium Halides, CaF2, Rutile, Anti-rutile, betacristobalite), other crystal systems (Bismuth tri-iodide, Corundum, Rhenium Trioxide etc.), Mixed oxides (Spinel, Perovskite, Ilmenite). The properties of solids**,** Mechanical properties Electrical properties, Impact on nanoscience: Nanowires, Optical properties, Magnetic properties. Point Defects in crystals- stoichiometric and non-stoichiometric defects, Line defect, surface defects, Liquid Crystals- Classification and application.

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

CHE 10504

ORGANIC CHEMISTRY LAB 1

Credit 2 **36 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 and purify and recrystallize the product.	Analyze
C.O. 2: Plan and perform synthetic procedures, chromatographic separation and purification of organic compounds.	Understand
C.O. 3: Separate organic compounds from the organic binary mixture and identify the functional group(s) present.	Analysis

Separation and identification of the components of organic binary mixtures.

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

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. Mann, F.G. Saunders, B.C. Practical Organic Chemistry, 4th Ed., Pearson Education India, 2009.

3. Furniss, B.S. Hannaford, A.J. Smith, P.WG. Tatchell, A.R. Vogel’s Textbook of Practical Organic Chemistry, 5th Ed., Longman, 1989.

CHE 10505

INORGANIC CHEMISTRY LAB 2

Credit 2

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Apply the concepts of qualitative and quantitative aspects in inorganic preparation	Apply
C.O. 2: Estimate the amount of any given substance gravimetrically	Apply
C.O. 3: Synthesize metal complexes and characterize them by various physicochemical methods.	Apply

Gravimetric analysis: Estimation of Barium, sulphate,Calcium, iron, nickel.

Inorganic preparations: Preparation of Tris(oxalato)manganese(III), Tetrapyridinesilver(II) peroxidisulphate, Tris(acetylacetonato) iron(III), Bis(N,N-diethyldithiocarbamato)nitrosyliron(I), Optical isomers of tris(ethylenediamine)cobalt(III)chloride, Nitropentamminecobalt(III) chloride, Tri(acetylacetonato)manganese(III), Tris(thiourea) copper(I) sulphate, Phenyl lithium, Tetraphenyl lead, Ferrocene, Phosphonitrilic chloride.

Recommended Text Books:

1. A.I. Vogel, A Text Book of Quantitative Inorganic Analysis, Longman, 1966
2. G. Pass, H. Sutcliffe. Practical Inorganic Chemistry 2nd edition, Chapman & Hill. 1974.
3. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Edn., Pearson Education, Noida, 2013.

CHE 10601
INORGANIC CHEMISTRY – III
(Group Theory and Concepts in Inorganic Chemistry)

Credit 4 **72 hours.**

Course Outcome After completion of the full course the student should be able to	**Cognitive level**
C.O.1: Analyze the symmetry of any given molecule and assign the point group	Analyse
C.O.2: Apply the principles of symmetry and group theory in structure, bonding and spectral characteristics of molecules	Apply
C.O.3: Identify the structure-activity relationship of simple molecules based on their qualitative molecular orbitals.	Apply
C.O.4: Assess the strength of various acids and bases and their reactivity.	Evaluate
C.O.5: Explain behavior of different non-aqueous solvent systems towards different reactions.	Apply

UNIT I	**18 hrs**
Matrix representation of symmetry operations, similarity transformation and classes, Symmetry classification of molecules into point groups (Schoenflies symbol)- Reducible and Irreducible representations - Great Orthogonality theorem and its consequences (statement only, proof not needed), Character tables, Reduction formula, construction of character tables for point groups with order ≤6-, Interpretation of character tables. Wave functions as bases for irreducible representations, Direct product. Application of symmetry to predict polar and chiral compounds	
UNIT II	**18 hrs**
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, Applications of Group theory for molecular vibration, symmetry of group vibrations. Selection rules and applications to IR, Raman and electronic spectra.	
UNIT III	**12 hrs**

Qualitative molecular orbital theory, symmetry of molecular orbitals, MOs for homo and heteronuclear diatomic molecules, H_2 to F_2, HF, CO, NO, BeH_2, CO_2, H_2O, BH_3, NH_3, B_2H_6. Importance of frontier molecular orbitals, Shape, energy and reactivity of molecules.	
UNIT IV	**12 hrs**
Relative strength of acids, Pauling rules, Lewis concept, Generalized acid-base concept, Measurement of acid base strength, Lewis acid –base interactions, steric and solvation effects, acid–base anomalies, Pearson's HSAB concept, acid-base strength and hardness and softness, Symbiosis, theoretical basis of hardness and softness, electronegativity and hardness.	
UNIT V	**12 hrs**
Chemistry in non-aqueous solvents reactions in NH_3, liquid SO_2, solvent character, reactions in SO_2, acetic acid, solvent character, reactions in H_2SO_4 and some other solvents. Molten salts, Green solvent: supercritical CO_2, Ionic liquids and deep eutectic solvents.	

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

CHE 10602

ORGANIC CHEMISTRY III

(Organic Chemistry Reactions, Reagents, Photochemistry & Pericyclic Reactions)

Credit 4 **72 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, oxidizing agents, organometallic and organo-nonmetallic reagents with mechanistic illustrations	Apply
C.O. 2: Analyze the reagents and conditions for the synthesis of specific target molecules.	Analyse
C.O. 3: Identify the mechanism and the product in a given reaction under photochemical conditions.	Apply
C.O. 4: Apply the concepts of Frontier orbital theory in the study of pericyclic reactions.	Apply

UNIT I	**16 hrs**
Reagents for oxidation and reduction: Chromium reagents, activated DMSO, osmium tetroxide, selenium dioxide, singlet oxygen, peracids, hydrogen peroxide, periodic acid, lead tetraacetate, ozonolysis, Woodward and Prevost hydroxylation, Wacker process, Oppenauer oxidation, Sharpless, Shi and Jacobsen asymmetric epoxidations. Catalytic hydrogenations (heterogeneous-Palladium/Platinum/Rhodium and Nickel, homogeneous-Wilkinson), metal hydride reduction- $LiAlH_4$, DIBAL-H, Red-Al, $NaBH_4$ and $NaCNBH_3$. Selectrides, trialkylsilanes and trialkyl stannane. Birch reduction, hydrazine and diimide reduction. Meerwein-Ponndorf-Verley reaction, Enzymatic reduction using Baker's yeast.	
UNIT II	**14 hrs**
Synthetic applications of organometallic and organo-nonmetallic reagents: Hydroboration reactions, Sakurai allylation, Gilman's reagent, Ullmann and Glaser coupling reactions. Suzuki coupling, Sonogashira coupling, Heck reaction, Buchwald–Hartwig coupling, Negishi coupling and Stille coupling. Metathesis processes of electrophilic carbene complexes (first- and second-generation Grubbs catalyst), ROMP, Dötz reaction and methylenation of carbonyls. 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 III	**16 hrs**
Chemistry of carbonyl compounds: Reactivity of carbonyl groups in aldehydes, ketones, carboxylic acids, esters, acyl halides and amides. Substitution at carbonyl carbon, mechanisms of ester hydrolysis, substitution at α-carbon, aldol and related reactions. Grignard reaction, Reformatsky reaction, Claisen, Darzen, Dieckmann, Knoevenagel and Stobbe condensations. Perkin, Prins, Mannich, Stork-enamine reactions. Conjugate additions, Michael additions and Robinson annulation. Favorskii reaction, Julia olefination, Peterson olefination. Preparation of 1,2-, 1,3-, 1,4- and 1,5-diketones from simple ketones. Reaction with phosphorous and sulfur ylides.	
UNIT IV	**14 hrs**
Photochemistry: Unimolecular and bimolecular processes in the excited states, mechanism of important photochemical reactions, Paterno-Buchi reaction, Norrish Type I and Type II fragmentation, di-pi-methane rearrangement, Barton reaction, photochemistry of olefins, arenes, cyclohexadienones; photoreduction and photo-oxygenation	
UNIT V	**12 hrs**
Pericyclic reactions: Study of the principle of conservation of orbital symmetry: Orbital symmetry diagrams for cycloaddition and electrocyclic reactions. Aromatic Transition State Theory and The Generalized Woodward – Hoffmann rule applied to cycloaddtions, Electrocyclic reactions, Sigmatropic rearrangements and Chelotropic reactions. Pericyclic Reactions in Organic Synthesis: Stereochemistry and Regiochemistry of 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. Pericyclic reactions in Organic synthesis – case studies.	

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), 5th ed., Springer, 2008.
4. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
5. N. J. Turro, V. Ramamurthy, J. C. Scaiano, Modern Molecular Photochemistry of Organic Molecules, University Science Books, 2010.
6. E. V. Anslyn, D. A. Dougherty, Modern Physical Organic Chemistry. University Science Books, 2006.
7. H. R. Crabtree, The Organometallic Chemistry of the Transition Metals, 6th ed., John Wiley & Sons, 2014.
8. S. D. Burke, R. L. Danheiser, Handbook of Reagents for Organic Synthesis, John Wiley & Sons, 1999

CHE 10603
PHYSICAL CHEMISTRY III
(Chemical Kinetics, Surface Chemistry and Catalysis)

Credit 4 **72 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 kinetics of various reactions and obtain the rate constants for reactions in gaseous state and solutions.	Analyse
C.O.2: Calculate the thermodynamic parameters from kinetic data	Apply
C.O.3: Apply the basic principles of acid-base and enzyme catalysis to any given kinetic data.	Apply
C.O.4: Explain the fundamentals of photochemical and photophysical processes and energy/electron transfer.	Apply

UNIT – 1	**14 hrs**
Complex Reactions: Parallel, Consecutive and Opposing reactions, Steady state Approximation, Kinetics of chain reactions - Photochemical reactions H_2-Cl_2 and H_2-Br_2 reaction, Organic decomposition reactions-Rice Herzfield mechanism (acetaldehyde and ethane), Branched Chain Reactions, Explosions-Somenoff Hinshelwood mechanism (H_2-O_2 reaction), Termolecular reactions.	
UNIT – 2	**16 hrs**
Molecular reaction dynamics: Reactive encounters, Theories of reaction rates-Collision Theory recap), Activated Complex Theory- Potential energy surface, Erying equation, Comparative evaluation of collision and transition state theory, Thermodynamic treatment of reaction rates. Theory of unimolecular reactions- Lindemann Mechanism, Modifications to Lindemann mechanism- Hinshelwood, RRK and RRKM model. Termolecular reactions. Molecular beam methods, Stripping and rebound mechanism.	
UNIT – 3	**16 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	**14 hrs**

Catalysis: Catalysis and Inhibition, Homogeneous and heterogeneous Catalysis – Transition state theory, General mechanism. General Mechanism of homogeneous catalysis- Arrhenius and vant Hoff intermediates, Acid base catalysis- specific and general acid catalysis, Enzyme catalysis- Michaelis-Menten Mechanism, Competitive and non competitive inhibition. Kinetics of Surface catalysis: Unimolecular and bimolecular Surface reactions. Kinetics of adsorption- Langmuir Hinshelwood mechanism and Rideal-Eley mechanism. Autocatalysis- Oscillatory reactions- Lotka- Volterra, Oregonator, Brussellator.	
UNIT – 5	**12 hrs**
Photochemistry: Photochemistry and photophysics- Applications, Excited state reactivity and life time, Excimers and Exciplex, Energy and electron transfer -Elementary idea, Quenching- Static and Dynamic, Stern Volmer equation, Photocatalysis- Elementary principles.	

Recommended Text Books:

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

CHE 10604

ORGANIC CHEMISTRY LAB II

Credit 2 **36 hours**

Course Outcome After the completion of the course the student will be able to	Cognitive level
C.O. 1: Plan and perform synthetic procedures, chromatographic separation and purification of organic compounds.	Understand
C.O. 2: Use Chemical Abstracts, Scopus, Organic Synthesis collective volumes on web etc. to search, analyse and collect chemical information.	Apply
C.O. 3: Use software to Draw the structures and schemes of organic molecules and reactions.	Apply

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

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

Part III : Drawing the structures of organic molecules and reaction schemes by Proprietary and open source computer software.

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

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,

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

CHE 10605
PHYSICAL CHEMISTRY LAB II

Credit 2 **36 hours**

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1: Execute and perform experiments based on pH metry, potentiometry, conductometry and colorimetry	Evaluate

pH Metry: Acid-base titrations involving strong and weak acids/bases.

Conductometry: Acid-base titrations involving strong and weak acids/base, Determination of degree of ionization of weak electrolytes

Potentiometry: Acid-base titrations involving strong and weak acids/base, Determination of degree of ionization of weak electrolytes. Redox titrations.

Colorimetry: Verification of Beer-Lambert Law, Estimation of ferric iron by colorimetry, Estimation from real samples

Recommended Text Books:

1. Gurtu, J. N., Gurtu, A., Advanced Physical Chemistry Experiments, 6^{th} Ed.,Pragati Prakashan,2014.
2. Yadav, J. B., Advanced Practical Physical Chemistry, 36^{th} Ed., Krishna Prakashan, 2016.
3. D.P Shoemaker, G.W Garland, J.W Nibler, Experiments in Physical Chemistry, 5^{th} Edn., McGraw Hill.

CHE 10701
INORGANIC CHEMISTRY – IV
(Reaction Mechanism and Organometallic Chemistry)

Credit 4 **72 hours**

Course Outcome After completion of the full course the students should be able to	**Cognitive level**
C.O. 1: Understand the basic concepts and applications of organometallics.	Apply
C.O. 2: Evaluate the structure, bonding and reactions of organometallic compounds and metallocenes.	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: Explain the stability of transition metal complexes, their reactivity, and the mechanisms of ligand substitution	Apply

UNIT I	**14 hrs**
Organometallic Chemistry. Compounds with transition metal to carbon bonds: eighteen electron rule; classification of ligands, nomenclature, metal-metal multiple bonding, Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, EAN rule as applied to carbonyls, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. Preparation and structure of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni. π-acceptor behaviour of CO, synergic effect and use of IR data to explain extent of back bonding.	
UNIT II **hrs**	**14**
σ donor ligands – metal alkyl, aryl complexes; σ donor/π acceptor ligands, – metal alkenyls, alkynyls, carbenes, carbynes, isocyanide, phosphines, fluxionality of ligands – structure, bonding, spectra, preparation and reactions. σ, π donor/π acceptor ligands – olefin complexes, alkyne, allyl, enyl complexes Metallocene- ferrocene, titanocene, zircanocene, arene complexes, cycloheptatriene, cyclooctatetraene, cyclobutadiene complexes, fluxionality of ligands – structure, bonding, preparation, reactions and spectroscopy	
UNIT III	**14 hrs**
Metal–Metal bonds and Transition metal clusters; preparation, properties and spectroscopy. Parallels with nonmetal chemistry- isolobal analogy. Application of Wade-Mingos-Lauher rules in predicting the	

structure of organometallic clusters Organo-lithium aluminium, magnesium, zinc and titanium compounds – their preparations, properties, reactions, bonding and applications. Spectral analysis and characterization of organometallic complexes.	
UNIT IV	**14 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 V	**16 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 References:

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

CHE 10702
ORGANIC CHEMISTRY IV
(Natural Products, Dyes and Pigments)

Credit 4 **72 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Devise 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: Explain the chemical properties, structure and application of organic dyes and pigments.	Understand

UNIT I	**16 hrs**
Heterocyclic compounds: Nomenclature of three to seven-membered aliphatic heterocyclic compounds containing one heteroatom (N, O). Five and six-membered heteroaromatic compounds containing one to four heteroatoms (N, O, S). Indole, quinoline and isoquinoline. Structure and general preparations. Alkaloids: Isolation and classification, isolation, and structure elucidation based on degradative reactions (quinine and atropine). Biosynthesis of quinine and papaverine. Basic introduction to flavonoids and anthocyanin: Structure, properties and biological functions.	
UNIT II	**14 hrs**
Dyes and pigments: structure and properties of dyes and pigments, natural and synthetic dyes, classification, azodyes, triarylmethane dyes, anthraquinone dyes, indigoid dyes, cyanine dyes, sulfur dyes, nitro and nitroso dyes. Edible dyes (food colours) with examples, dyes for electro-optical application, textile colourants and cosmetic colourants, porphyrins, chlorins, bactereochlorins and phthalocyanines.	
UNIT III	**16 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.	
UNIT IV	**14 hrs**

Lipids: Classification, biological functions, fatty acids -omega 3 and omega 6 fatty acids, extraction and refining of oils and fats. 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.	
UNIT V	**12 hrs**
2D NMR spectroscopy, emission and chiroptical spectroscopy.	

Recommended Text Books:

1. I. L. Finar, Organic Chemistry Volumes 1 & 2, 6th ed., Pearson Education Asia, 2004.
2. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
3. N. R. Krishnaswamy, Chemistry of Natural Products; A Unified Approach, Universities Press, 1999.
4. S. P. Bhutani, Chemistry of Biomolecules, 2nd ed., CRC Press, 2020.
5. R. O. C. Norman, Principles of Organic Synthesis, 2nd ed., Chapman and Hall, 1978.
6. J. A. Joule, K. Mills, Heterocyclic Chemistry, 5th ed., Wiley, 1998.
7. A. Gürses, M.Açıkyıldız, K. Güneş , M. S. Gürses, Dyes and Pigments, Springer, 2016.
8. Heinrich Zollinger, Colour Chemistry: Synthesis, Properties and applications of organic dyes and pigments, VCH, Germany, 1987.
9. D.L.Pavia, G.M. Lampman, G.S.Kriz, Introduction to Spectroscopy, A Guide for Students of Organic Chemistry, 3rd ed., Thomson. 2004.
10. R. M. Silverstein, G.C. Bassler, T. C. Morril, Spectroscopic identification of organic compounds, John Wiley, 1991.
11. Spectral databases (RIO DB of AIST, for example)

CHE 10703

THEORETICAL CHEMISTRY – II

(Approximations and Chemical Bonding)

Credit 4 **72 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Derive the Schrodinger equation for multielectronic atoms and interpret the results.	Apply
C.O. 2: Derive the variational principle and perturbation theory, use them to calculate properties for simple systems of chemical interest.	Analyze
C.O. 3: Explain Hartree-Fock Theory and semiempirical Huckel MO treatment and its application to polyelectronic molecules	Analyze
C.O. 4: Classify various basis sets and justify its use for a specific problem	Analyze
C.O. 5: Explain different chemical properties of molecules by drawing molecular orbitals	Analyze

UNIT I	**16 hrs**
Solving the Schrodinger equation of Hydrogen atom: Separation into three equations and solutions, Theta and phi equations and solutions, Spherical harmonics, Radial equations and solutions, Laguerre equation and Laguerre polynomials. Solutions of wave functions and energies, quantum numbers and their importance, Radial wave function and radial distribution functions, angular wave function, Shapes of s, p, d and f atomic orbitals. Hamiltonian operators, Wave functions and energy of H like systems, Orbital functions, Postulate of electron spin-orbital and spin functions. Zeeman effect. Spin Orbitals and their construction, Antisymmetric wave functions, Pauli's antisymmetry principle.	
UNIT II	**12 hrs**
Many body problems, Born –Oppenheimer Approximations, Independent particle method, Drawbacks. Variational method – theory, proof and general treatment of linear variational problem- Application to systems such as Hydrogen, Helium and various other cases. Hamiltonian operator for multielectronic atom, Perturbation method: Time Independent perturbation for non- degenerate –first order, perturbation corrections to energy and wave functions, Application of this to various systems such as particle in a box, helium atom.	
UNIT III	**8 hrs**
Self-Consistent Field approximation- Hartree's proposal, Pauli's antisymm principle, Pauli exclusion principle, Electron spin, Constructing Antisymmetric spin incorporated wave functions for He, excited	

state of He – various electronic states, term symbols. Hartree-Fock Self Consistent Field method for multielectronic atoms. The Coulomb and Exchange Operators, The Fock Operator, Koopmans' theorem, Brillouin's theorem, Slater's treatment of complex atoms, Slater orbitals, Slater determinant and wave function.	
UNIT IV	**18 hrs**
Chemical Bonding- Application to H_2^+, MO and VB treatment of H_2 molecule- Comparison. Concept of σ, σ*, π, π* orbitals and their characteristics, hybrid orbitals, calculation of coefficients of AO used in sp, sp^2 and sp^3 hybrid orbitals, interpretation of geometry, Valence bond model of H_2, Hybridisation of H_2O, BF_3, NH_3 and CH_4. Hartree Fock -Roothaan method - LCAO approximation - Restricted HartreeFock (RHF) for closed shell systems, Restricted open HF (ROHF), and Unrestricted HF (UHF) methods, Empirical, Semi empirical and ab initio methods. Basis functions- Slater Type Orbital and Gaussian Type Orbitals. Contracted and primitive. Basis sets. Minimal, multiple zeta, split-valence, polarized and diffused. Pople style basis sets, designation of basis set size –Dunnings correlation consistent basis sets, Relativistic effects - Effective core potential, ECP.	
UNIT V	**18 hrs**
HMOT: Pi bonding in simple molecules, HMO method for linear conjugated hydrocarbons, linear, cyclic, polycyclic, heterocyclic; ethylene, 1,3-butadiene, allyl radical, cation and anion, aromatic hydrocarbons, cyclopropenyl systems, cyclobutadiene, benzene, naphthalene, thiophene. Calculation of charge distribution, bond orders and reactivity. QMOT: Applications of Molecular Orbital Theory in Understanding reactions and Mechanisms. Qualitative MO theory. Group orbitals. Frontier Orbitals, Substituent effects on frontier orbitals, HSAB concept, Nucleophiles and Electrophiles, Perturbation theory of reactivity. Application of Frontier Orbital theory in studying ionic and radical reactions, Ambident electrophiles, α-effect.	

Recommended Text Books:

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

9. Jensen, F., “Introduction to Computational Chemistry”, 3rd Edition, Wiley, 2017.
10. Young, D., “Computational Chemistry – A Practical Guide”, Wiley, 2001.
11. Anslyn, E. V.; Dougherty, D. A. Modern Physical Organic Chemistry. University Science Books,

CHE 10704

SPECTROSCOPY

Credit 4 **72 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Explain the factors affecting the intensity and broadening of lines in spectra and methods to enhance the sensitivity.	Understand
C.O.2: Explain the principles of rotational, vibrational, Raman, electronic, fluorescence, NMR and ESR.	Understand
C.O.3: Calculate energy required for a particular type of energy transition and determine the parameters involved.	Apply
C.O.4: Apply various theoretical aspects to various spectroscopic techniques for prediction of different spectroscopic observations.	Analyse
C.O.5: Identify various d-d transitions and interpret the electronic spectra of any given transition metal complex.	Apply
C.O.6: Interpret the ESR and Mossbauer spectra of given transition metal complex.	Evaluate

UNIT I	**10 hrs**
Population of energy levels. Induced quantum transitions. Integrated absorption coefficient. Einstein's coefficients of absorption. Basis of selection rules, transition moment integral. Beer's Law. Induced absorption and emission of radiation by molecules, Factors affecting the intensity and width of spectral lines, Methods to reduce line broadening.	
UNIT II	**16 hrs**
Rotational and vibrational energies of diatomic molecules. Linear molecules, Symmetric top and asymmetric top molecules. Rotation spectra: Diatomic and polyatomic molecules, Selection rule. Vibration spectra of diatomic molecules, Morse potential of real molecules, overtones, combination and hot bands, Fermi resonance, rotational character of vibration spectra. Coupling of rotation and vibration. Parallel and perpendicular bands. Vibration spectra of polyatomic molecules, Normal modes of vibrations of polyatomic molecules. Raman Spectroscopy. Rotational Raman spectra. Vibrational Raman spectra, Resonance Raman, mutual	

exclusion principle. Selection rules and applications to IR and Raman spectra, Surface enhanced Raman spectroscopy.

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

UNIT III	18 hrs

Electronic energy states of molecules. Selection rules for electronic transitions, Vibrational structure of electronic bands. Electronic transitions and absorption bands. Electronic spectra of diatomic and polyatomic molecules, its relation to electronic arrangement and symmetry of molecules. Different types of electronic transitions, Electronic spectra of conjugated systems.

Principle of fluorescence spectroscopy, Quenching of fluorescence, Mechanisms of quenching

Magnetic resonance spectroscopy: Theory of nuclear magnetic resonance, Chemical shifts, Factors affecting chemical shifts, First order and second order spectra, relaxation effects. Fourier Transformation in NMR, Measurement of relaxation time, Spin echo, NOE, 2D NMR, NQR Spectroscopy. MRI, Solid state NMR.

Principle of electron spin resonance.

UNIT IV	14 hrs

Microstates, Atomic term symbols Free ion terms for dn configuration, Splitting of terms in octahedral and tetrahedral octahedral fields, Correlation diagram for d2 configuration in octahedral geometry, d-d transitions, Selection rules for electronic transitions.

Orgel diagram – splitting for d1, d9, high spin d4, d6, splittings for high spin d2, d3, d8 and d7. Calculation of Dq, B and β

Tanabe Sugano diagrams – splittings for low spin dn systems

Electronic Spectral interpretation of some coordination compounds

Consequence of Jahn Teller effect on the electronic spectra of coordination compounds

Charge transfer spectra, Electronic spectra of lanthanide and actinide complexes

UNIT V	14 hrs

Electronic paramagnetic resonance spectroscopy: Electronic Zeeman effect, Zeeman Hamiltonian and EPR transition energy. EPR spectrometers, presentation of spectra. The effects of electron Zeeman, nuclear Zeeman and electron nuclear hyperfine terms in the

Hamiltonian on the energy of the hydrogen atom. Second order effect. Hyperfine splittings in isotropic systems, spin polarization mechanism and McConnell's relations Anisotropy in g-value, EPR of triplet states, zero field splitting, Kramer's rule, survey of EPR spectra of first row transition metal ion complexes.

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

Recommended Text Books:

1. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed., Pearson, 2014.
2. F. A. Cotton, G. Wilkinson, C. A, Murillo, M. Bochmann Advanced Inorganic Chemistry, 6th ed., Wiley-Interscience: New York, 1999.
3. J.E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
4. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3rd ed., ELBS, 1999.
5. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd ed., John Wiley and Sons, 1994.
6. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd ed., BH, 1997.
7. R. S.Drago, Physical Methods for Chemists, 2nd ed., Saunders College Publishing, 1992.
8. C. E. Housecroft, A. G. Sharpe, Inorganic Chemistry, 5th ed., Pearson, 2018.
9. W. L. Jolly, Modern Inorganic Chemistry, 2nd ed., McGraw-Hill, New York, 1991.
10. Solid state chemistry: an introduction, Lesley Smart and Elaine Moore, 4th ed. Taylor and Francis, 2012.
11. Earnshaw, A. Introduction to Magnetochemistry, Academic Press, 1968.
12. Carlin, R.L. Magnetochemistry, Spinger-Verlag, Berlin, 1986.
13. P. W. Atkins, Physical Chemistry 8th ed., W. H. Freeman, New York, 2006.
14. R. A. Alberty, Physical Chemistry 8th ed., Wiley, New York, 1994.
15. G. M. Barrow, Introduction to Molecular Spectroscopy, McGraw Hill, New York, 1962
16. C. N. Banwell, Fundamentals of Molecular Spectroscopy, 4th ed., Tata McGraw Hill, 1996.
17. H. Gunther, NMR Spectroscopy, 2nd ed., John Wiley, 2005.

CHE 10705

INDUSTRIAL CHEMISTRY LAB

Credit 2 **36 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 of natural resources to value added chemicals	Create

1. Preparation of soap and detergents
2. Preparation of margarine
3. Preparation and physical property measurement of natural, synthetic rubber, fiber.
4. Extraction of essential oils
5. Extraction of natural flavors
6. Preparation of Biogas
7. Waste water treatment
8. Preparation and characterization of nanomaterials
9. Preparation of silicon from Rice Husk
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., Krishna Prakashan, 2016.

CHE 10706

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

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 Students 3rd Edition, Michigan Publishing, 2012.
2. Stephen Bailey, Academic Writing, A Handbook for International Student,5th Edition, Routledge, Taylor & Francis, 2018.

CHE 10801

ADVANCED ANALYTICAL AND INSTRUMENTATION TECHNIQUES -I

Credit 4 **72 hours**

Course Outcome After completion of the full course the students should be able to	**Cognitive level**
C.O.1: Understand the basic principles and instrumentation aspects of various electroanalytical, chromatographic, and thermo-analytical techniques	Understand
C.O.2: Interpret the data obtained from analytical techniques	Evaluate
C.O.3: Use the electroanalytical, chromatographic, and thermo-analytical techniques for qualitative and quantitative evaluations	Analyze

UNIT I	**14 hrs**
Potentiometry: different types of indicator electrodes, limitations of glass electrode, applications in pH measurements, other types of ion selective electrodes, solid, liquid, gas sensing and specific types of electrodes, biomembrane, biological and biocatalytic electrodes as biosensors, importance of selectivity coefficients. CHEMFETS- importance of specially designed amplifier systems for ion selective electrode systems. Potentiometric titrations- types and applications.	
UNIT II	**14 hrs**
Electrogravimetry- electrogravimetry without potential control, controlled potential electrogravimetry, applications. Coulometry- constant current and constant potential coulometry, applications- primary and secondary coulometry, advantages of coulometric titrations Conductance measurement – conductometric titrations.	
UNIT III	**14 hrs**
Polarography – current – voltage curve, DME-components of polarographic current, supporting electrolyte, polarographic maxima. Half-wave potential, Applications of Polarography. Voltammetry - different types, Theory and applications. Stripping analysis. Amperometric titrations – Different types and Applications Impedance spectroscopy, Voltammetric sensors – individual and simultaneous analysis-Case study	
UNIT IV	**12 hrs**
Thermal methods of Analysis TG, DTA and DSC - Instrumentation and Theory – Factors affecting TGA - effect of atmosphere on DTA. TG of copper sulphate pentahydrate and calcium oxalate monohydrate. Application of thermal methods for identification of substances.	

UNIT V	18 hrs
Solvent extraction and Solid phase extraction, Basic principles of solvent extraction Distribution law-Liquid-liquid extractions, synergistic extraction, Batch extraction, continuous extraction, Counter current extraction, super critical fluids Chromatography: Basic principles, adsorption, differential migration, effect and choice of stationary and mobile phases, Classification of chromatographic techniques., Thin layer chromatography, Paper chromatography, column chromatography, gas chromatography, ion exchange chromatography, gel permeation chromatography, supercritical fluid chromatography and size exclusion chromatography, Important applications of chromatographic techniques	

Recommended References:

1. J.M. Mermet, M. Otto, R. Kellner, Analytical Chemistry, Wiley-VCH, 2004.
2. D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8th Edn., Saunders College Pub., 2007.
3. J.G. Dick, Analytical Chemistry, R.E. Krieger Pub., 1978.
4. J.H. Kennedy, Analytical Chemistry: Principles, Saunders College Pub., 1990.
5. G.H. Jeffery, J. Bassett, J. Mendham, R.C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Edn., John Wiley& sons,1989.
6. C.L. Wilson, D.W. Wilson, Comprehensive Analytical Chemistry, Elsevier, 1982.
7. G.D. Christian, J.E. O’Reilly, Instrumental Analysis, Allyn & Bacon, 1986.
8. R.A. Day, A.L. Underwood, Quantitative Analysis, Prentice Hall, 1967.
9. H.A. Laitinen, W.E. Harris, Chemical Analysis, McGraw Hill, 1975.
10. F.W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, Blackwell Science, 2000.
11. Contemporary Instrumental Analysis, Kenneth A. Rubinson, Judith F. Rubinson, Prentice Hall, New Jersey, 2000.
12. Wilson & Wilson’s, Comprehensive Analytical Chemistry, Volume 47, Modern Instrumental Analysis, Edited by S. Ahuja, N. Jespersen, Reed Elsevier India Private Ltd., Noida, 2006.
13. Journal of Chromatography Library, Volume 3, Liquid Column Chromatography-A Survey of Modern Techniques and Applications, Edited by Z. Deyl, K. Macek, J. Janak, Elsevier Scientific Publishing Company, Amsterdam, 1975.
14. Gas Chromatography, John Willett, John Wiley & Sons, Singapore, 1991.
15. Fundamentals of Analytical Chemistry, Doughlas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch, 9th Ed., Cengage Learning, 2014.
16. Allen J. Bard, Larry R. Faulkner, Electrochemical Methods-Fundamentals and Applications, John Wiley & Sons, New York, 1980.

CHE 10802

ADVANCED PHYSICAL CHEMISTRY

Credit 4 **72 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Apply the principles of statistical thermodynamics to solids and gases	Apply
C.O.2: Explain the basics of transport phenomena and electrokinetic effects and explain entropy production for physical and chemical processes.	Apply
C.O.3: Interpret structure-property relations in liquids and kinetics of polymerisation.	Apply

UNIT I	**16 hrs**
Transport properties- Diffusion, effusion, Viscosity, Thermal conductivity. Heat capacity of solids- Einstein and Debye theory. 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 II	**14 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 III	**16 hrs**
Linear Non-equilibrium thermodynamics: General theory, Local entropy production, balance equation for concentration. Energy conservation in open systems. Entropy balance equation. Forces and Fluxes, Steady state and local equilibrium conditions. Linear phenomenological laws. Phenomenological coefficient, Systems with heat, matter and electrical transport, Onsager Reciprocal relation, Application to Diffusion -Thermal diffusion, Thermal Osmosis and electrokinetic effects, Soret Coefficient, Seebeck effect.	
UNIT IV	**14 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 superhydrophobicity/super-oleophilcity.
UNIT V **12 hrs**
Polymers: General Properties, Molecular weight determination, Kinetics and thermodynamics of polymerization.

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, Julio De Paula, Physical Chemistry, Oxford University Press, $10^{th}/11^{th}$ edn, 2017/2018
5. D. A. McQuarrie, Physical Chemistry- A Molecular Approach, South Asian Edn., 2008.
6. M. Dole, Introduction to Statistical Thermodynamics, Prentice Hall, London, 1997.
7. D. A. McQuarrie, Statistical Thermodynamics, South Asian Edn., 2008.
8. I. Prigogine, Introduction to Thermodynamic Irreversible Processes, 3^{rd} ed., Wiley Interscience, 1968.
9. S. R. de Groot, P. Mazur, Non-equilibrium Thermodynamics, Dover Publications, 2011.
10. G. Lebon, D. Jou, J. Casas, Understanding Non-equilibrium Thermodynamics, Springer. 2008.
11. S. Kjelstrup, D. Bedeaux, E. Johannessen, J. Gross, Non-Equilibrium Thermodynamics for Engineers: Second Edition, World Scientific Publishing Company, 2017.
12. D. Kondepudi and I. Prigogine, Modern Thermodynamics: From Heat Engines to dissipative Structures, Wiley, New York.

CHE 10803

ADVANCED ORGANIC CHEMISTRY

Credit 4 **72 hours**

Course Outcome After the completion of the course, the student will be able to	**Cognitive level**
C.O.1: Analyze the conformational effects on the reactivity of reactions.	Apply
C.O.2: Analyze the reagents and conditions for the synthesis of specific target molecules.	Analyse
C.O.3: Describe strategies for the stereospecific/stereoselective organic transformations towards chiral target molecules.	Apply
C.O.4: Construct a synthetic pathway for simple to complex organic molecules by retrosynthetic approach.	Apply

UNIT I	**16 hrs**
Reaction mechanisms and conformational effects on reactivity - Ester hydrolysis, alcohol oxidations, S_N2 reactions, elimination reactions, epoxidation by intramolecular closure of halohydrins, strain-modulated reactivity, epoxide openings (S_N2), electrophilic additions to olefins, rearrangement reactions, conformational and stereoelectronic effects on reactivity. Stereoselective reactions of cyclic compounds. Reactions on small rings. Stereochemical control in six-membered rings. Stereochemistry of bicyclic compounds. Reactions with cyclic intermediates/transition states	
UNIT II	**14 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 III	**12 hrs**

Protecting groups- protection and deprotection of hydroxyl, carboxylic acids, and carbonyls in aldehydes and ketones, amines, alkenes and alkynes. Chemo- & regioselective protection and deprotection. Functional group equivalents, reversal of reactivity (Umpolung).
UNIT IV **16 hrs**
Disconnection approach-introduction to retrosynthesis, basic principles, synthons, and synthetic equivalents. Monofunctional and bifunctional disconnection, One group C-X and two groups C-X disconnections, one group C-C and two groups C-C disconnections. Computers in organic synthesis – introduction to softwares –SYNTHIA, MAPOS, AiZynthFinder.
UNIT V **14 hrs**
Retrosynthetic analysis: Longifoline, Corey lactone, Djerassi - Prelog lactone and D-luciferin. Application of AiZynthFinder to retrosynthetic analysis.

Recommended Text Books:

1. P.S.Kalsi: Stereochemistry, Conformation and Mechanism, 3rd Edn., New Age Publications.
2. E. L. Eliel and S. H. Wilen: Stereochemistry in Organic Compounds, 1994, John Wiley.
3. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2^{nd} ed., Oxford University Press, 2012.
4. P. S. Kalsi, Stereochemistry, Conformation and Mechanism, 9^{th} ed., New Age Publications, 2017.
5. T. Tsuji, Transition Metal Reagents and Catalysts: Innovations in Organic Synthesis, John Wiley & Sons, 2000.
6. S. Warren, Organic Synthesis: The Disconnection Approach, 2^{nd} ed., John Wiley, 2008.
7. E. Robert, Gawley, J. Aube, Principles of Asymmetric Synthesis, 2^{nd} ed., Elsevier, 2012.
8. T.W. Greene, P. G. M. Wuts, Protecting Groups in Organic Synthesis, 2^{nd} ed., John Wiley, 1991

CHE 10804

COMPUTATIONAL CHEMISTRY LAB

Credit 2 **36 hours**

Course Outcome After the completion of the course, the student will be able to	**Cognitive level**
C.O. 1: Carry out computational chemistry software to perform calculations	Apply
C.O. 2: Analyze the calculated results and interpret the results to solve chemical puzzles	Analyze

Computational calculations using available programme package:

- Constructing molecular structures or models
- Molecular geometry optimization
- Conformational analysis
- Thermodynamic and spectroscopic properties
- Molecular orbital analysis
- Electron density and electrostatic potential map.

Recommended Text Books:

1. Foresman, J. and Frisch, A.,“ Exploring chemistry with electronic structure methods”, Guassian Inc, 2000.
2. Cramer, C. J., “Essentials of Computational Chemistry- Theories and Models”, 2nd Edition, Wiley, 2004
3. Jensen, F., “Introduction to Computational Chemistry”, 3rd Edition, Wiley, 2017.
4. Young, D., “Computational Chemistry – A Practical Guide”, Wiley, 2001.

CHE 10805
OPEN ENDED LAB

Credit 4

Course Outcome After completion of the full course the student should be able to	**Cognitive level**
C.O.: identify and hypothesise an independent research problem and write a literature review	Analyse

Students will identify a research problem and carry out a literature survey on selected topic. A project will be undertaken with guidance from concerned teacher. There will be report submission and evaluation at the end of the semester.

CHE 10901

ADVANCED ANALYTICAL AND INSTRUMENTATION TECHNIQUES II

Credit 4 **72 hours**

Course Outcome After completion of the full course the students should be able to	**Cognitive level**
C.O.1: Gain an in-depth understanding of working principles of advanced analytical and surface characterization techniques	Understand
C.O.2: Choose and optimize the right techniques and instrumentation configuration for a particular analysis	Evaluate
C.O.3: Analyse the data for differentiation and quantitative evaluation of analytes and surfaces	Analyze

Unit 1	**14 hrs**
Gas chromatography – basic instrumental set up-inlets, carriers, columns, detectors and comparative study of TCD, FID, ECD, NPD and MS. Qualitative and quantitative studies using GC, Preparation of GC columns, packet columns and capillary columns, selection of stationary phases of GLC, Choosing the parameters-Temperature, Length of the column, Sample size, Flow rate, CHN analysis by GC, Case study	
Unit 2	**14 hrs**
Capillary electrophoresis-migration rates and plate heights, instrumentation, sample introduction, detection methods, applications. Capillary gel electrophoresis. Capillary isotachophoresis. Isoelectric focusing. Capillary electro chromatography-packed columns. Micellar electro kinetic Chromatography	
Unit 3	**16 hrs**
Separation process, Eddy diffusion, Mass transfer, Longitudinal diffusion, Retention parameters in HPLC-Capacity factor, Retention time, Retention volume, Peak width, Total number of theoretical plates, Height equivalent of a theoretical plate, Resolution and retention time, Solvent delivery systems, Detectors Instrumentation and functioning of HPLC, Types of HPLC - Modes of separation in HPLC-adsorption chromatography, reversed phase chromatography, ion pair chromatography, ion exchange chromatography Solubility and retention in HPLC	

Method development in HPLC - Selection of mobile phase and optimization, Preparation of sample, Selection of column and solvent, HPLC method validation, HPLC Analysis -Case study Dos and Don'ts in HPLC - Troubleshooting in HPLC	
Unit 4	**14 hrs**
Measurement of alpha, beta, and gamma radiations, neutron activation analysis and its applications. Principle and applications of isotope dilution methods, Radioimmunoassay (RIA), Immunoradiometric assay (IRMA), Enzyme linked immunosorbent assay (ELISA)-Principles and practical aspects	
Unit 5	**14 hrs**
Chemical Analysis of surfaces: Surface preparations-ion scattering spectrometry secondary ion scattering microscopy (SIMS)-Auger election spectroscopy-ESCA instrumentation and application. Electron Microscopies, Basic principles of TEM and SEM, Elemental analysis, XRD, Scanning probe microscopies an overview, Basic principles of AFM and STM, Case study	

Recommended References:

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

CHE 10902
INSTRUMENTATION LAB

Credit 4 **72hours**

Course Outcome **A**fter the completion of the course the student will be able to	Cognitive level
After the completion of the course the student will be able to understand the operation principles of various instruments and perform experiments using them	Evaluate

1. REFRACTOMETRY: Variation of refractive index with composition and Determination of unknown composition
2. Cyclic voltammetry determination oxidation reduction potentials, HOMO and LUMO levels
3. UV-VIS-NIR spectroscopy: Band Gap Estimation of thin films
4. Fluorescence spectroscopy: Emission Excitation spectral analysis, Fluorescence quantum yield, fluorescence lifetime, quenching
5. Synthesis and characterization of Nano-silver
6. Raman spectroscopy: Vibrational analysis of compounds, Surface Enhanced Raman spectroscopy
7. TGA-DTA Thermal analysis
8. GC
9. Diffused reflectance spectroscopy
10. Determination of Alkalinity of water; DO and BOD and COD of waste water.

Recommended Text Books:

1. J. N. Gurtu, and A. Gurtu Advanced Physical Chemistry Experiments, 6 th Edn., Pragati Prakashan, 2014.
2. B. P. Levitt, Findlay's Practical Physical Chemistry, 9 th Edn, Longman Group Ltd.
3. Vogel's text book of quantitative chemical analysis, Fifth Edition.

CHE 10903
MINI PROJECT

Credit 4

Course Outcome After completion of the full course the student should be able to	**Cognitive level**
C.O.: identify and hypothesise an independent research problem.	Analyse

Students will identify a research problem and carry out an independent project under the supervision of concerned teacher and shall submit a report. There will be an evaluation at the end of the semester.

CHE 11001 and 11002
PROJECT AND COURSE VIVA

Credit 16+2

The students shall carry out research project in reputed research laboratory for the entire semester.

The students shall submit a project report on the research work carried out.

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

Cochin University of Science and Technology
Department of Mathematics

Integrated MSc in Mathematics

Syllabus approved by the

Board of Studies of Physical and Mathematical Sciences

(2023 admission onwards)

Detailed Course Structure for Integrated MSc Mathematics

SEMESTER: 1							
Semester Credit: 22 (Core: 19; Elective: 3) Cumulative Credit: 22							
Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
ENG 10101	English – I	Core (ACE 1)	2	2-0-0	50	50	100
MAL 10101 HIN 10101 GER 10101	**Language** Malayalam – I* Hindi – I* German – I*	Core (ACE 2)	2	2-0-0	50	50	100
MAT 10101	Calculus 1	Core** (MDC 1)	3	3-1-0	50	50	100
MAT 10102	Basic Analysis 1	Core	4	4-1-0	50	50	100
PHY 10101	General Physics I	Interdepartmental Core	3	3-1-0	50	50	100
PHY 10102	Physics Lab 1 (Mechanics)	Interdepartmental Core	2	0-0-4	100	-	100
STA 10101	Statistical Methods for Data	Interdepartmental Core	3	3-1-0	50	50	100
BIO 10101	General Biology	Interdepartmental Elective***	3	3-1-0	50	50	100
CSP 10101	Computer Science 1	Interdepartmental Elective***	3	3-1-0	50	50	100
CHE 10101	General Chemistry I	Interdepartmental Elective***	3	3-1-0	50	50	100

AEC – Ability enhancement Course; MDC – Multidisciplinary Course; VAC – Value Added Course; SEC – Skill Enhancement Course

- *Any one language paper is to be chosen
- **Will also be offered as an interdepartmental core/elective
- *** Student shall select any one interdepartmental elective

SEMESTER: 2

Semester Credit: 22 (Core: 19; Elective: 3) Cumulative Credit: 44

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
ENG 10201	English – II	Core (ACE 3)	2	2-0-0	50	50	100
MAL 10201 HIN 10201 GER 10201	**Language** Malayalam – II* Hindi – II* German – II*	Core (ACE 4)	2	2-0-0	50	50	100
MAT 10201	Calculus II	Core** (MDC 2)	3	3-1-0	50	50	100
MAT 10202	Basic Analysis II	Core	4	4-1-0	50	50	100
PHY 10201	General Physics II	Interdepartmental Core	3	3-1-0	50	50	100
PHY 10202	Physics Lab 2 (Waves and Optics)	Interdepartmental Core	2	0-0-4	100	-	100
STA 10201	Probability and Distributions	Interdepartmental Core	3	3-1-0	50	50	100
BIO 10203	Biophysical Chemistry	Interdepartmental Elective***	3	3-1-0	50	50	100
CSP 10201	Computer Science II	Interdepartmental Elective***	3	3-1-0	50	50	100
CHE 10201	General Chemistry II	Interdepartmental Elective***	3	3-1-0	50	50	100

- *Any one language paper is to be chosen
- **Will also be offered as an interdepartmental core/elective
- *** Student shall select any one interdepartmental elective

SEMESTER: 3

Semester Credit: 22 (Core: 19; Elective: 3) Cumulative Credit: 66

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10301	Calculus III	Core* (MDC 3)	3	3-1-0	50	50	100
MAT 10302	Matrix Theory I	Core	4	4-1-0	50	50	100
PHY 10301	General Physics III	Interdepartmental Core	3	3-1-0	50	50	100
PHY 10302	Physics Lab 3 (Electricity and Magnetism)	Interdepartmental Core	2	0-0-4	100	-	100
STA 10301	Statistical Inference	Interdepartmental Core	3	3-1-0	50	50	100
STA 10301	Environmental Science	Interdepartmental Core (VAC 1)	4	4-1-0	50	50	100
BIO 10301	Human Diseases and Healthcare Management	Interdepartmental Elective**	3	3-1-0	50	50	100
CSP 10301	Computer Science III	Interdepartmental Elective**	3	3-1-0	50	50	100
CHE 10301	General Chemistry III	Interdepartmental Elective**	3	3-1-0	50	50	100

- *Will also be offered as an interdepartmental core/elective
- ** Student shall select any one interdepartmental elective

SEMESTER: 4

Semester Credit: 23 (Core: 20, Elective: 3) Cumulative Credit: 89

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10401	Basic Group Theory	Core	4	4-1-0	50	50	100
MAT 10402	Matrix Theory II	Core	4	4-1-0	50	50	100
MAT 10403	Elementary Complex Analysis	Core	4	4-1-0	50	50	100
MAT 10404	Basics in Python Programming	Core	3	3-1-0	50	50	100
MAT 10405	Basics in Python Programming Lab	Core	2	0-0-4	100	-	100
Sxxxx	Skill Enhancement Course# (SEC 1)	Elective	3	0-0-3	100	-	100
STA 10401	Applied Statistics	Interdepartmental Core	3	3-1-0	50	50	100

Student shall select the course from a bouquet of courses offered by various departments

SEMESTER: 5

Semester Credit: 23 (Core: 16; Elective: 7), Cumulative Credit: 112

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10501	Real Analysis I	Core	4	4-1-0	50	50	100
MAT 10502	Complex Analysis	Core	4	4-1-0	50	50	100
MAT 10503	Group Theory	Core	4	4-1-0	50	50	100
MAT 10504	Linear Algebra and Geometry	Core	4	4-1-0	50	50	100
Sxxxxxx	Skill Enhancement Course# (SEC 2)	Elective	3	0-0-3	100	-	100
MAT 1050x	Elective I	Elective	4	4-1-0	50	50	100

SEMESTER: 6

Semester Credit: 23 (Core: 12; Elective: 7), Cumulative Credit: 135

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10601	Real Analysis II	Core	4	4-1-0	50	50	100
MAT 10602	Ring Theory	Core	4	4-1-0	50	50	100
MAT 10603	Ordinary Differential Equations	Core	4	4-1-0	50	50	100
MAT 106xx	Elective I	Elective	4	4-1-0	50	50	100
MAT 106xx	Elective II	Elective	4	4-1-0	50	50	100
Sxxxxxx	Skill Enhancement Course# (SEC 3)	Elective	3	0-0-3	100	-	100

LIST OF ELECTIVE COURSES OFFERED IN V AND VI SEMESTERS:-

MAT 10505 / MAT 10605: Discrete Mathematics

MAT 10506 / MAT 10606: Linear Programming

MAT 10507 / MAT 10607: Elements of Applied Mathematics

MAT 10508 / MAT 10608: Introduction to Optimization Techniques

MAT 10509 / MAT 10609: Metric Topology

MAT 10510 / MAT 10610: Fuzzy Mathematics

MAT 10511 / MAT 10611: Introduction to Optimization in Machine Learning

MAT 10512 / MAT 10612: Elementary Number Theory

SEMESTER: 7

Semester Credit: 20 (Core: 20, Internship: 2*) Cumulative Credit: 157

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10701	Linear Algebra	Core	4	4-1-0	50	50	100
MAT 10702	Real Analysis	Core	4	4-1-0	50	50	100
MAT 10703	Measure and Integration	Core	4	4-1-0	50	50	100
MAT 10704	Groups and Rings	Core	4	4-1-0	50	50	100
MAT 10705	Topology I	Core	4	4-1-0	50	50	100
MAT 10706	Internship*	Internship	2	--	--	50	50

*Students must do a internship within or outside the institution (online also permitted) during the semester break to attain an additional 2 credits.

SEMESTER 8

Semester Credit: 20 (Core: 20) Cumulative Credit: 177

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10801	Fields and Modules	Core	4	4-1-0	50	50	100
MAT 10802	Functional Analysis	Core	4	4-1-0	50	50	100
MAT 10803	Complex Analysis	Core	4	4-1-0	50	50	100
MAT 10804	Functions of Several Variables and Geometry	Core	4	4-1-0	50	50	100
MAT 10805	Computational Mathematics Laboratory	Core	4	4-1-0	50	50	100

Students who wish to exit with a BSc Honors with research must do a research project of 12 credits, for additional credits, or can opt out a maximum of 2 core papers offered in 8th semester. The eligibility to opt for research project and the papers that can be omitted shall be decided by the student in consultation with the project supervisor and with the approval of the department council.

SEMESTER 9

Semester Credit: 20 (Core: 12; Elective: 8) Cumulative Credit: 197

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10901	Operator Theory	Core	4	4-1-0	50	50	100
MAT 10902	Ordinary Differential Equations and Integral Equations	Core	4	4-1-0	50	50	100
MAT 10903	Elective I	Elective	4	4-1-0	50	50	100
MAT 109xx	Elective II	Elective	4	4-1-0	50	50	100
XXX 109xx	Elective III	Interdepartmental Elective	4	4-1-0	50	50	100

SEMESTER 10

Semester Credit: 20 (Core: 8; Elective: 12) Cumulative Credit: 217

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 11001	Partial Differential Equations and Variational Problems	Core	4	4-1-0	50	50	100
MAT 11002	Probability Theory	Core	4	4-1-0	50	50	100
MAT 110xx	Elective I	Elective	4	4-1-0	50	50	100
MAT 110xx	Elective II	Elective	4	4-1-0	50	50	100
MAT 110xx	Elective III	Elective	4	4-1-0	50	50	100

NB: Hybrid mode, MOOC and/or Project (6 months – 4 credits / 1 year – 8 credits) can be taken instead of elective courses in IX and X semester (For enabling students for 1 year project work in National Labs/Industry/Abroad)

LIST OF ELECTIVE COURSES OFFERED IN IX AND X SEMESTERS:-

MAT 10905 : Topics in Applied Mathematics (Inter-departmental elective)
MAT 10906/ MAT 11006 : Advanced Linear Algebra
MAT 10907/ MAT 11007 : Discrete Framelets
MAT 10908/ MAT 11008 : Harmonic Analysis
MAT 10909/ MAT 11009 : Integral Transforms
MAT 10910/ MAT 11010 : Functions Of Several Variables
MAT 10911/ MAT 11011 : Advanced Spectral Theory
MAT 10912/ MAT 11012 : Banach Algebras And Spectral Theory
MAT 10913/ MAT 11013 : Number Theory
MAT 10914/ MAT 11014 : Representation Theory Of Finite Groups
MAT 10915/ MAT 11015 : Algebraic Topology
MAT 10916/ MAT 11016 : Differential Geometry
MAT 10917/ MAT 11017: Algebraic Graph Theory
MAT 10918/ MAT 11018 : Wavelets
MAT 10919/ MAT 11019 : Advanced Optimization Methods and Machine Learning
MAT 10920/ MAT 11020 : Commutative Algebra
MAT 10921/ MAT 11021 : Graph Theory
MAT 10922/ MAT 11022 : C*-Algebra and Representation Theory
MAT 10923/ MAT 11023 : Reproducing Kernel Hilbert Spaces
MAT 10924/ MAT 11024 : Topology II

Cochin University of Science and Technology
Department of Mathematics

Mathematics Core Papers

(Semester: 1, 2 and 3)

Departmental / Interdepartmental Core

(Offered for students opting Mathematics, Physics, Chemistry and Statistics)

Semester I
MAT 10101 - Calculus I

Number of credits: 3
Number of hours per week: 4 hrs
Total No. of Hours: 72 hours

Objective: This course introduces the basic concepts from calculus that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of calculus.

Prerequisites : Set theory, Operations on sets, functions, The set of natural numbers, Set of integers, Set of rational numbers, Set of real numbers and the set of Complex numbers.

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).
2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).
3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).
4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Real Numbers and the Real Line, Coordinates, Lines, and Increments, Functions, Shifting Graphs, Trigonometric Functions, Rates of Change and Limits, Rules for Finding Limits, Target Values and Formal Definitions of Limits, Extensions of the Limit Concept, Continuity and Tangent Lines.
(Sections: Preliminaries 1, 2, 3, 4, 5, 1.1, 1.2, 1.3, 1.4, 1.5 and 1.6 of Text book 1).

Module 2: The Derivative of a Function, Differentiation Rules, Derivatives of Trigonometric Functions, The Chain Rule, Implicit Differentiation and Rational Exponents.
(Sections 2.1, 2.2, 2.4, 2.5 and 2.6 of Text book 1).

Module 3: Extreme Values of Functions, The Mean Value Theorem, The First Derivative Test for Local Extreme Values, Graphing with y' and y''.
(Sections 3.1, 3.2, 3.3 and 3.4 of Text book 1).

Module 4: Indefinite Integrals, Differential Equations, Integration by Substitution-Running the Chain Rule Backward, Riemann Sums and Definite Integrals, Properties, Area, and the Mean Value Theorem, The Fundamental Theorem, Substitution in Definite Integrals.
(Section 4.1, 4.2, 4.3, 4.5, 4.6, 4.7 and 4.8 of Text book 1).

Semester II
MAT 10201 - Calculus II

Number of credits: 3
Number of hours per week: 4 hrs
Total number of Hours: 72 hours

Objective: This course introduces the basic concepts from calculus that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of calculus.

Prerequisites : This course is a continuation of Calculus I course offered in Semester I

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).
2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).
3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).
4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Areas Between Curves, Finding Volumes by Slicing, Volumes of Solids of Revolution, Lengths of Plane Curves.
(Sections: 5.1, 5.2, 5.3 and 5.5 of Text book 1).

Module 2: L Hopital's Rule, Basic Integration Formulas, Integration by Parts, Partial Fraction, Improper Integrals.
(Sections: 6.6, 7.1, 7.2. 7.3 and 7.6 of Text book 1).

Module 3: Limits of Sequences of Numbers, Theorems for Calculating Limits of Sequences.
(Sections: 8.1 and 8.2 of Text book 1).

Module 4: Infinite series, The integral test for series of non negative terms, Comparison tests for series of non negative terms, Ratio and root test for series of non negative terms, Alternating Series, Absolute and Conditional Convergence. (Sections 8.3, 8.4, 8.5, 8.6 and 8.7 of text book 1).

Semester III
MAT 10301 - Calculus III

Number of credits: 3
Number of hours per week: 4 hrs
Total number of Hours: 72 hours

Objective: This course introduces the advanced concepts of calculus that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to become familiar with the advanced concepts and applications of calculus.

Prerequisites : This is a continuation course of Calculus II offered in Semester II.

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).

2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).

3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).

4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Conic Sections and Quadratic Equations, Classification of Conic Section by Eccentricity, Quadratic Equation and Rotations, Parametrization of Plane Curves, Calculus with Parametrized Curves, Polar coordinates, Cylindrical and Spherical coordinates, Vector valued functions and space curves, Arc length and the unit tangent vector, Curvature, torsion and the TNB frame.
(Sections 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, and 10.7 of the text book 1).

Module 2: Functions of several variables, Limits and continuity, Partial derivatives, Differentiability.
(Sections 12.1, 12.2, 12.3 and 12.4 of the text book 1).

Module 3: Linearization and Differentials, The chain rule, Partial derivatives with constrained variables, Directional derivatives, Gradient and tangent planes, Extreme values and saddle points, Lagrange multipliers, Taylor's formula.
(Sections 12.5, 12.6, 12.7, 12.8, 12.9 and 12.10 of the text book 1).

Module 4: Double integrals, Areas, Double integral in polar form, Triple integrals in Rectangular coordinates, Masses, moments in three dimension.
(Sections 13.1, 13.2, 13.3, 13.4 and 13.5 of the text book).

Cochin University of Science and Technology
Department of Mathematics

Mathematics Elective Papers

(Semester: 1, 2 and 3)

Interdepartmental Elective

(Offered for students opting Biology, Physics, Chemistry and Statistics. Not for Mathematics)

Semester I
MAT 10103 - Mathematical Methods I

Number of credits: 3
Number of hours per week: 4 hrs
Total No. of Hours: 72 hours

Objective: This course introduces basic Complex analysis and Differential equations techniques which are important tools in all branches of science.

Outcome: After completing the course, the student is expected to become familiar with basic Complex analysis and Differential equations techniques.

Prerequisites: Basic theory, formulas and techniques of differential and integral calculus of one variable.

Text book:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition. John Wiley and Sons, Inc., New York, (1999).

Reference books:

1. Calculus, Vol I (Second Edition), Tom M. Apostol, Wiley Student Edition, (2006).
2. Calculus and Analytic Geometry (Ninth Edition), George.B.Thomas and Ross.L.Finney, Pearson Education, Inc, (2006)
3. Complex variables and Applications (5th Edition) , J. W. Brown, R.V. Churchill, McGrawHill Higher Education, (1990).
4. Complex Analysis (3rd edition), L.V. Ahlfors, McGrawHill Book Company, (1979).

Syllabus

Module 1: Basic concepts and ideas, Geometric meaning, Exact equations, Linear differential equations, Applications Homogeneous Linear differential equations of second order.
(Chapter 1, Section 2.1 of Text book 1).

Module 2: Homogeneous Linear differential equations of second order with constant coefficients, Euler Cauchy equations, Existence and uniqueness theory, Wronskian, Non homogeneous equations, Solutions by undetermined coefficients and by variation of parameters.
(Sections 2.2-2.3, Sections 2.6-2.10 of Text book 1).

Module 3: Complex Numbers, Polar form, Analytic Function, Cauchy-Riemann Equations, Elementary Functions, logarithm.
(Section 12.1-12.4, 12.6-12.8 of Text Book 1).

Module 4: Complex Integration, Cauchy's Integral Theorem and Integral Formula (without proof), Higher Derivatives (without proof).
(Section 13.1-13.4 of the Text Book).

Semester II
MAT 10203 - Mathematical Methods II

Number of credits: 3
Number of hours per week: 4 hrs
Total No. of Hours: 72 hours

Objective: This course introduces Laplace Transform and Fourier series which are important tools in all branches of science. Also, Numerical Methods in General, Numerical Methods in Linear Algebra and Numerical Methods for Differential Equations are introduced. This course also introduces the abstract concept of Groups which is useful in all branches of science.

Outcome: After completing the course, the student is expected to become familiar with Laplace Transform and Fourier series and their applications to various branches. It is also expected that the student will get basic ideas about numerical methods. The student is expected to have basic ideas related to the abstract mathematical structures Groups.

Prerequisites: Basic theory, formulas and techniques of differential and integral calculus of one variable.

Text books:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition. John Wiley and Sons, Inc., New York, (1999).
2. Symmetry An Introduction To Group Theory And Its Applications, Roy McWeeny, Dover Publications, Inc. (2002).

Reference books:

1. Calculus, Vol I (Second Edition), Tom M. Apostol, Wiley Student Edition, (2006).
2. Calculus and Analytic Geometry (Ninth Edition), George.B.Thomas and Ross.L.Finney, Pearson Education, Inc, (2006)
3. Complex variables and Applications (5th Edition) , J. W. Brown, R.V. Churchill, McGrawHill Higher Education, (1990).
4. Complex Analysis (3rd edition), L.V. Ahlfors, McGrawHill Book Company, (1979).
5. Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, 2017.

Syllabus

Module 1: Power Series, Power series representation of Analytic functions,Taylor series and Maclaurin series, Practical methods for power series. Laurent Series (without proof), Singularities and Zeros, Residue integration Method, Evaluation of Real Integrals, Laplace Transform, Transforms of Derivatives and integrals, Second Shifting theorem.
(Section 14.2-14.5, 15.1-15.4, 5.1-5.3 of Text Book 1).

Module 2: Periodic functions, Fourier Series, Functions of any period, Half-Range Expansion, Fourier Series (Contd.): Complex Fourier Series, Forced Oscillations, Fourier Transform.
(Section 10.1-10.10 of Text Book 1).

Module 3: Introduction, Solution of Equations by Iteration, Interpolation, Spline Interpolation, Numeric Integration and Differentiation, Linear Systems: Gauss Elimination (Tutorials: using sage,scilab).
(Section 17.1-17.5 of the Text Book)

Module 4: Symbols and the Group Property, Definition of a Group, The Multiplication Table, Powers, Products, Generators, Subgroups, Cosets, Classes, The Invariant Subgroups, the Factor Group, Homomorphisms and Isomorphisms.
(Chapter 1, Sections 1.1-1.7 of the Text Book 2).

Semester III
MAT 10303 - Matrix Theory and Graph Theory

Number of credits: 3
Number of hours per week: 4 hrs
Total No. of Hours: 72 hours

Objective: This course introduces the basic concepts from linear algebra and Graph Theory that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of linear algebra and Graph Theory .

Text books:

1 Advanced Engineering Mathematics, Erwin Kreyszig, 10th Edition. John Wiley and Sons, Inc., New York, (2011).

2 John Clark Derek Allen Holton - A first look at graph theory, Allied Publishers, 1991.

Reference books:

1 S. Kumaresan: *Linear Algebra: A Geometric Approach*, PHI Learning, 2009.

2 Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.

3 R Balakrishnan and K Ranganathan: *A Text Book of Graph Theory*, Springer.

Syllabus

Module 1: Matrices, Vectors: Addition and Scalar Multiplication, Matrix Multiplication, Linear Systems of Equations, Gauss Elimination, Linear Independence, Rank of a Matrix, Vector Space, Solutions of Linear Systems: Existence, Uniquenes.
(Sections 7.1-7.5 of Text book 1).

Module 2: Determinants, Cramer s Rule, Inverse of a Matrix, GaussJordan Elimination, The Matrix Eigenvalue Problem, Determining Eigenvalues and Eigenvectors, Some Applications of Eigenvalue Problems, Symmetric, Skew-Symmetric, and Orthogonal Matrices.
(Sections 7.7, 7.8, 8.1 - 8.3 of Text book 1).

Module 3: An introduction to graph: Definition of a Graph, More definitions, Vertex Degrees, Sub graphs, Paths and cycles, the matrix representation of graphs.
(Sections 1.1 to 1.7 of Text book 2)

Module 4: Trees. Definitions and Simple properties, Bridges, Spanning trees, Cut vertices and Connectivity, Eulers Tours, the Chinese postman problem, Hamiltonian graphs, The travelling salesman problem.
(Sections 2.1, 2.2, 2.3, 2.6, 3.1, 3.2, 3.3, and 3.4 of Text book 2).

Cochin University of Science and Technology
Department of Mathematics

Mathematics Core Papers

(Semester: 1 - 6)

Core papers

(Offered only for students opting Mathematics)

Semester I
MAT 10102 - Basic Analysis I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the structure of Natural Numbers. This course is planned to introduce the notions real number system, Convergence of sequence and series.
Learning Outcomes: 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 real numbers, sequence of real numbers, limit theorems and series convergence tests.

UNIT 1: Introduction to Natural numbers and Rational Numbers, The set of all Real numbers, Completeness axiom (Sections 1, 2, 3 and 4)

UNIT 2: Extended real number system.Limit of sequence (Sections 5, 6, 7 and 8)

UNIT 3: Limit theorems, Monotone Sequences and Cauchy Sequences (Sections 9, and 10)

UNIT 4: Subsequences, Limsups and Liminfs, Series (Sections 11, 12 and 14)

UNIT 5: Alternating Series and Integral Tests, Continuous functions, Properties of continuous functions (Sections 15, 17 and 18)

Text Book: Kenneth A. Ross Elementary Analysis: The Theory of Calculus, Second Edition, Springer-Verlag (2013).

References:-

1. Terence Tao, Analysis I and II, Third Edition, Springer 2016.

2. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, Fourth Edition, Wiley India Edition (2011).

3. N.L Carothers, Real Analysis, Wiley 2000.

4. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).

5. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).

6. A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).

7. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).

8. S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)

Semester II
MAT 10202 - Basic Analysis II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the notion of continuous functions. This course is planned to introduce the notions continuity, Convergence of sequence and series of functions and some metric space notions.
Learning Outcomes: This course is planned to build up the important notions of continuity and uniform continuity. After the completion of this course, the student should able to be familiar with these notions and some metric space versions of them.

UNIT 1: Uniform Continuity, Limit of functions, Power Series (Sections 19, 20 and 23)

UNIT 2: Uniform Convergence, More on Uniform Convergence, Differentiation and Integration of Power Series (Sections 24, 25 and 26)

UNIT 3: Basic Properties of the Derivative, The Mean Value Theorem (Sections 28 and 29)

UNIT 4: LHospitals Rule, Taylors Theorem (Sections 30 and 31)

UNIT 5: The Riemann Integral, Properties of the Riemann Integral, Fundamental Theorem of Calculus (Sections 32, 33 and 34)

Text Book: Kenneth A. Ross Elementary Analysis: The Theory of Calculus, Second Edition, Springer-Verlag (2013).

References:-

1. Terence Tao, Analysis I and II, Third Edition, Springer 2016.
2. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, Fourth Edition, Wiley India Edition (2011).
3. N.L Carothers, Real Analysis, Wiley 2000.
4. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).
5. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).
6. A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).
7. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).
8. S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)

Semester III
MAT 10302 - Matrix Theory I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the basic concepts from linear algebra that are required in all branches of science.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of linear algebra. They will also get familiar with computer software MATLAB.

Text books:

1 Ron Larson: *Elementary Linear Algebra*, 8th Edition, Cengage Learning, 2016.

Reference books:

1 S. Kumaresan: *Linear Algebra: A Geometric Approach*, PHI Learning, 2009.

2 Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.

3 Michael Artin: *Algebra*, Pearson Prentice Hall, . Linear Algebra: A First Course with Applications

Syllabus

Module 1: Introduction to Systems of Linear Equations, Gaussian Elimination and Gauss-Jordan Elimination, Applications of Systems of Linear Equations, Computational Aspects using computer software MATLAB.
(Sections 1.1 - 1.3 of Text book 1).

Module 2: Operations with Matrices, Properties of Matrix Operations, The Inverse of a Matrix, Elementary Matrices, Computational Aspects using computer software MATLAB.
(Sections 2.1 - 2.4 of Text book 1).

Module 3: Markov Chains, More Applications of Matrix Operations, The Determinant of a Matrix, Determinants and Elementary Operations, Computational Aspects using computer software MATLAB.
(Sections 2.5,2.6, 3.1, 3.2 of Text book 1)

Module 4: Properties of Determinants, Applications of Determinants, Vectors in R^n, Vector Spaces, Subspaces of Vector Spaces, Computational Aspects using computer software MATLAB.
(Sections 3.3, 3.4, 4.1 to 4.3 of Text book 1).

Module 5: Spanning Sets and Linear Independence, Basis and Dimension, Rank of a Matrix and Systems of Linear Equations, Computational Aspects using computer software MATLAB.
(Sections 4.4 to 4.6 of Text book 1).

Semester IV
MAT 10401 - Basic Group Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the basic concepts from algebra that are required in all branches of science.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of algebra. They will also get familiar with computer algebra system GAP.

Text books:

1 Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, year.

Reference books:

1 M. Artin: *Algebra*, Pearson Prentice Hall, 2007.

2 J.B. Fraleigh: *A first Course in Abstract Algebra*, Seventh Edition, Pearson, 2014.

3 M.A. Amstrong: *Groups and Symmetry*, Springer, 1997.

4 I.N. Herstein: *Topics in Algebra*, Wiley, 2006.

Syllabus

Module 1: Introduction to Groups: Symmetries of a Square, The Dihedral Groups; **Groups:** Definition and Examples of Groups, Elementary Properties of Groups, Exercises using Computer Algebra System GAP. (PART 2 Chapters 1, 2 of Text book 1).

Module 2: Finite Groups; Subgroups: Subgroup Tests, Examples of Subgroups, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 3 of Text book 1).

Module 3: Cyclic Groups: Properties of Cyclic Groups, Classification of Subgroups of Cyclic Groups, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 4 of Text book 1)

Module 4: Permutation Groups: Cycle Notation, Properties of Permutations, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 5 of Text book 1)

Module 5: Isomorphisms Definition and Examples, Cayleys Theorem, Properties of Isomorphisms, Automorphisms, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 6 of Text book 1)

Semester IV
MAT 10402 - Matrix Theory II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course serves as a second course in linear algebra as a continuation of the Matrix Theory I course..

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of linear algebra. They will also get familiar with computer software MATLAB.

Text books:

1 Ron Larson: *Elementary Linear Algebra*, 8th Edition, Cengage Learning, 2016.

Syllabus

Module 1: Review of Vector space, Applications of Vector Spaces, Inner Product Spaces, Computational Aspects using computer software MATLAB.
(Sections 4.7 - 4.8, 5.1-5.2 of Text book 1).

Module 2: 5.3 Orthonormal Bases, Gram-Schmidt Process, Mathematical Models and Least Squares Analysis, Applications of Inner Product Spaces, Computational Aspects using computer software MATLAB.
(Sections 5.3 - 5.5 of Text book 1).

Module 3: 6.1 Introduction to Linear Transformations, The Kernel and Range of a Linear Transformation, Matrices for Linear Transformations, Computational Aspects using computer software MATLAB.
(Sections 6.1-6.3 of Text book 1)

Module 4: Transition Matrices and Similarity, Applications of Linear Transformations Eigenvalues and Eigenvectors, Computational Aspects using computer software MATLAB.
(Sections 6.4, 6.5 and 7.1 of Text book 1).

Module 5: Diagonalization, Symmetric Matrices and Orthogonal Diagonalization, Applications of Eigenvalues and Eigenvectors, Computational Aspects using computer software MATLAB.
(Sections 7.2 to 7.4 of Text book 1).

References:-

1. Arindama Singh: *Introduction to Matrix Theory*, Springer, 2021.
2. Kenneth Hoffman and Ray Kunze *Linear Algebra*, Second Edition, PHI (1975).
3. M. Artin, Algebra, Prentice-Hall, (1991)
4. Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.
5. S.Kumaresan, *Linear Algebra: A Geometric Approach*, Fist Edition PHI Learning (2009).
6. Sheldon Axler, *Linear Algebra Done Right*, Second Edition, Springer, (1997).

Semester IV
MAT 10403 - Elementary Complex Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the concepts and results from complex variable theory that are required for further study of advanced mathematics.

Outcome: After completing the course, students will be 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.

5 S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser Boston, 2006.

Syllabus

Module 1. Sums and products, Basic Algebraic Properties, Further Properties, Vectors and Moduli, Complex conjugates, Exponential Form, Products and Power in Exponential Form, Argument of Products and Quotients, Roots of Complex Numbers, Examples, Regions in the Complex plane. (Sections 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 of the text book 1).

Module 2. Functions of Complex Variable, Mappings, Mappings by the Exponential Function, Limits, Theorems of Limits, Limits Involving the Point at Infinity. (Sections 12, 13, 14, 15, 16 and 17 of the Text book 1).

Module 3. Continuity, Derivatives and Differentiation Formulas. Cauchy-Riemann Equations, Sufficient Conditions for Differentiability, Polar Coordinates. (Sections 18, 19, 20, 21, 22 and 23 of the text book 1).

Module 4. Analytic Functions, Examples and Harmonic Functions. The Exponential Function, The Logarithmic Function, Some Identities Involving Logarithms, Complex Exponents, Trigonometric Functions Hyperbolic Functions. (Sections 24, 25, 26, 29, 30, 32, 33, 34 and 35 of the text book 1).

Module 5. Derivatives of Functions w(t), Definite Integrals of Functions w(t), Contours, Contour Integrals, Some Examples. Upper Bounds for Moduli of Contour Integrals, Antiderivatives and CauchyGoursat Theorem. (Sections 33, 37, 38, 39, 40, 41 43, 44, and 46 of the text book 1).

Semester IV
MAT 10404 - Basics in Python Programming

Number of credits: 3
Number of hours per week: 4 hrs
Total number of Hours: 72 hours

Objective: This course introduces the basics in python programming that are required in all branches of science.

Outcome: After completing the course, the student is expected to become familiar with the fundamentals in python programming and will be able to use it in their branches of study.

Text books:

1 Kaswan, K. S., Dhatterwal, J. S. and Balamurugan, B. (2023). Python for Beginners. CRC Press.

2 Fuhrer, C., Solem, J. E., Verdier, O. (2021). Scientific Computing with Python: High-performance scientific computing with NumPy, SciPy, and pandas. Packt Publishing Ltd.

Reference books:

1 Langtangen, H. P. (2016). A primer on scientific programming with Python. Springer-Verlag Berlin Heidelberg.

2 Charles Dierbach, Introduction to Computer Science Using Python: A Computational Problem-Solving Focus, Wiley, 2013.

3 Kenneth A Lambert., Fundamentals of Python : First Programs, 2/e, Cengage Publishing,2016

4 Mark Lutz, Learning Python, 5th Edition, O'Reilly Media, Inc.

Syllabus

Module 1: Introduction- Python Software setup, Datatypes, Sequence types, special types, Operators and Operands, Input and Output Functions, Flow control statements
(Sections 1.6, 2, 3.1, 4.3-4.6, 5.1, 5.3, 5.4 of Text 1).

Module 2: Functions, Lambda, Modules, List Comprehensions, Object Oriented Programming
(Sections 6.1 - 6.8, 7.1 - 7.8, 11.1 - 11.6 of Text 1).

Module 3: Encapsulation, Inheritance, Error and Exception Handling, Numpy
(Sections 11.8- 11.9 of Text 1 & Sections 12.1 - 12.3, 14.1- 14.2 of Text 2)

Module 4: Python for Scientific Computing- Linear Algebra Arrays, Understanding SciPy, Solving Linear System in Python, Building Least square Models and application on Prediction Problems
(Sections 4.1- 4.9 of Text 2).

Module 5: Data Analysis with Pandas, Working with Matplotlib
(Sections 6.1- 6.3, 10.2 - 10.4 Text 2).

Semester V
MAT 10501 - Real Analysis I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course aims to provide the fundamentals of mathematical analysis such as axiomati introduction to the real number system, convergence of sequences and series, notion of continuous functions on metric spaces motivated from the real number system.

Outcome: Creative skills to better understand abstract concepts, skill to construct proofs.
Text book:

1 R.G. Bartle and D.N. Sherbert, *Introduction to Real Analysis*, Thired Edition, John Wiley & Sons (2000).

Reference books:

1 G.B folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.

2 Elias M. Stein, Rami Shakarchi: *REAL ANALYSIS Measure Theory, Integration, and Hilbert Spaces* Princeton University press.

3 Kenneth A. Ross *Elementary Analysis The Theory of Calculus* Springer-Verlag, New York, 2013.

4 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.

5 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.

6 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1. Sets and Functions, Mathematicle Induction, Finte and Infinite Sets, The Algebraic and Order Properties of $\mathbb{R}$, Absolute Value and Real Line and The completeness Property of $\mathbb{R}$. (Sections 1.1, 1.2, 1.3, 2.1, 2.2 and 2.3 of Text book 1).

Module 2. Applications of the Supremum Property, Intervals, Open and Closed Sets in $\mathbb{R}$, Compact Sets, Continuous Functions and Metric Spaces. (Sections 2.4, 2.5, 11.1, 11.2, 11.3 and 11.4 of Text book 1).

Module 3. Sequences and Their Limits, Limit Theorems, Monotone Sequences, Subsequences and the Bolzano-Weierstrass Theorem, The Cauchy Criterion and Properly Divergent Sequences. (Sections 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 of Text book 1).

Module 4. Introduction to Series, Limits of Functions, Limits Theorems and Some Extensions of Limit Concept. (Sections 3.7, 4.1, 4.2 and 4.3 of Text book 1).

Module 5. Continuous Functions, Combinations of Continuous Functions, Continuous Functions on Intervals, Uniform Continuity, Continuity and Gauges, Monotone and Inverse functions. (Sections 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6 of Text book 1).

Semester V
MAT 10502 - Complex Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the concepts and results from complex variable theory athat is required for further study of advanced mathematics.

Outcome: After completing the course, students will be equipped with the understanding of the fundamental concepts of complex variable theory, N

Prerequisites: Basic familiarity with formulas, techniques of differential and integral calculus, Natural Numbers and Integers.
Text books:

1 J. W. Brown and R. V. Churchill, Complex Variables and Applications (8th Edition), Mcgraw-Hill,(2009).

Reference books:

1 L. V. Ahlfors, Complex Analysis, Mcgraw-Hill, 1980.

2 J. B. Conway, Functions of One Complex Variable (2nd Edition), Springer-Verlag, 1978.

3 R. Greene and S. G. Krantz, Function Theory of One Complex Variable, 3rd Edition, GSM, Vol. 40, AMS, 2006.

4 T. W. Gamelin, Complex Analysis, Springer-Verlag, 2001.

5 S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser Boston, 2006.

Syllabus

Module 1. Cauchy Integral Formula, An Extension of the Cauchy Integral Formula, Some Consequences of the Extension, Liouvilles Theorem and the Fundamental Theorem of Algebra, Maximum Modulus Principle. (Sections 50, 51, 52, 53 and 54 of the text book 1).

Module 2. Convergence of Sequences, Convergence of Series, Taylor Series, Examples, Laurent Series, Examples. (Sections 55, 56, 57, 59, 60 and 62 of Text book 1).

Module 3. Absolute and Uniform Convergence of Power Series, Continuity of Sums of Power Series, Integration and Differentiation of Power Series, Uniqueness of Series Representations, Multiplication and Division of Power Series, Isolated Singular Points and Residues Cauchys Residue Theorem, Residue at Infinity. (Sections:63, 64, 65, 66, 67, 68, 69 and 71, of Text book 1).

Module 4. The Three Types of Isolated Singular Points, Residues at Poles, Examples, Zeros of Analytic Functions, Zeros and Poles, Behavior of Functions Near Isolated Singular Points.(Sections: 72, 73, 74, 75, 76 and 77 of Text book 1).

Module 5. Argument Principle, Rouches Theorem, Linear Transformations, Transformation $w = \frac{1}{z}$, Mapping of $\frac{1}{z}$, Linear fractional transformations, Mapping of the upper half plane. (Sections: 86, 87, 90, 91, 92, 93 and 95 of Text book 1).

Semester V
MAT 10503 - Group Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: The course is devoted to some of the basic concepts and results of Group Theory. This course aims to introduce students to some more sophisticated concepts and results of group theory as an essential part of general mathematical culture and as a basis for further study of more advanced mathematics.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts of Group theory. The student is expected to have knowledge of some fundamental results and techniques from the theory of finite groups. They should have an an understanding of the symmetries in the Euclidean plane.

Text books:

1 J.B. Fraleigh: *A first Course in Abstract Algebra*, Seventh Edition, Pearson, 2014.

2 Michael Artin: Algebra, Prentice-Hall India, New Delhi, 2007.

Reference books:

1 M.A. Amstrong: *Groups and Symmetry*, Springer, 1997.

2 Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, 2017.

3 I.N. Herstein: *Topics in Algebra*, Wiley, 2006.

Syllabus

Module 1: Review of group theory: Groups, Subgroups, Cyclic groups.
(Sections 4, 5, 6 of Text Book 1).

Module 2: Generating sets and Cayley digraphs, Groups of Permutations, Orbits, Cycles, Alternating Groups.
(Sections 7, 8, 9 of Text Book 1).

Module 3: Cosets and the Theorem of Lagrange, Direct Products and Finitely Generated Abelian Groups.
(Sections 10, 11, 13 of Text Book 1).

Module 4: Homomorphisms, Factor Groups, Factor-Group Computations and Simple Groups.
(Sections 14,15 of Text Book 1).

Module 5: Symmetry: Symmetry of plane figures, The group of motions of the Plane, Finite group of motions.
(Sections 5.1-5.3 of Text Book 2).

Semester V
MAT 10504 - Linear Algebra and Geometry

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the basic concepts from linear algebra and Group Theory that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of linear algebra and Geometry.

Text books:

1. S.Kumaresan, *Linear Algebra: A Geometric Approach*, First Edition PHI Learning (2009).
2. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

Reference books:

1. Sheldon Axler: *Linear Algebra Done Right*, 3rd edition. Undergraduate Texts in Mathematics, Springer, Cham, 2015.
2. Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.
3. Michael Artin: *Algebra*, Prentice Hall, Inc., Englewood Cliffs, NJ, 1991.
4. Gilbert Strang: *Introduction to Linear Algebra*, 4th Edition, Wellesley Cambridge Press; 2009.

Syllabus

UNIT 1: Lines and Quotient spaces, Geometric ideas, Some special linear transformations (Chapter 3, Sections 4.5 - 4.6 of Text book 1).

UNIT 2: Orthogonality, Geometricapplications, Orthonormal basis, Hyperplanes, Reflections (Sections 5.2 - 5.9 of Text book 1)

UNIT 3: Diagonalization, Classification of quadrics (Chapter 7, 8 of Text book 1)

Module 4: Triple integral in cylindrical and spherical coordinates, Substitution in Multiple integrals, Line integral, Vector fields, work, circulation and flux, Path independence, Potential functions and conservative fields. (Sections 13.6, 13.7, 14.1, 14.2 and 14.3 of the text book 2).

Module 5: Green's theorem in the plane, Surface area Surface integral, parametrized surface, Stoke's theorem and Divergence theorem. (Sections 14.4, 14.5, 14.6, 14.7 and 14.8 of the text book 2).

Semester VI
MAT 10601 - Real Analysis II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course aims to provide the fundamentals of mathematical analysis: notion of differentiability, The Riemann Integral, sequences and series of functions, uniformconvergence, and the interchange of limit operations and an invitation to the calculus of several real variables.

Outcome: After the completion of this course, student should be 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. (Sections 6.1, 6.2, 6.3 and 6.4 of Text book 1).

Module 2. The Riemann Integral, Riemann Integrable Functions, The Fundamental Theorem and Approximate Integration. (Sections 7.1, 7.2, 7.3 and 7.4 of Text book 1).

Module 3. Pointwise and Uniform Convergence, Interchange of Limits, The Exponential and Logarithmic Functions and Trigonometric Functions. (Sections 8.1, 8.2, 8.3 and 8.4 of Text book 1).

Module 4. Absolute Convergence, Test for Absolute Convergence, Test for Nonabsolute Convergence and Series of Functions. (Sections 9.1, 9.2, 9.3 and 9.4 of Text book 1).

Module 5. Definition and main properties of Generalized Riemann Integral, Improper and Lebesuge Integrals, Infinite Intervals. (Sections 10.1, 10.2 and 10.3 of Text book 1).

Semester VI
MAT 10602 - Ring Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course aims to introduce students to the basic concepts of ring theory.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts of ring theory.

Text books:

1 J.B. Fraleigh: *A first Course in Abstract Algebra*, Seventh Edition, Pearson, 2014.

Reference books:

1 Michael Artin: Algebra, Prentice-Hall India, New Delhi, 2007.

2 Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, 2017.

3 I.N. Herstein: *Topics in Algebra*, Wiley, 2006.

Syllabus

Module 1: Rings and Fields: Definitions and Basic Properties, Homomorphisms and Isomorphisms, Fields; Integral Domains: Divisors of zero and cancellation, Integral Domain, The Characteristic of a Ring.
(Section 18, 19 of Text Book 1).

Module 2: Fermat's and Euler's Theorems: Fermat's Theorem, Euler's Generalization, Application to Congruence Equations; The Field of Quotients of an Integral Domain: The Construction, Uniqueness.
(Section 20, 21 of Text Book 1).

Module 3: Rings of Polynomials: Polynomials in an Indeterminate, The Evaluation Homomorphisms, Factorization of polynomials over a field: The Division Algorithm in $F[x]$, Irreducible Polynomials, Unique Factorization in $F[x]$.
(Section 22, 23 of Text Book 1).

Module 4: Homomorphisms and Factor Rings: Homomorphisms, Properties of Homomorphisms, Factor Rings, Fundamental Homomorphism Theorem.
(Section 26 of Text Book 1).

Module 5: Prime and Maximal Ideals: Maximal Ideals, Prime Ideals, Prime Fields, Ideal Structure in $F[x]$, Application to Unique Factorization in $F[x]$.
(Section 26, 27 of Text Book 1).

Semester VI
MAT 10603 - Ordinary Differential Equations

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of Ordinary differential equations. Course aims to build an understanding of the classical models in terms of ordinary differential equations and pave the foundations for the study of Integral equations.
Learning Outcomes: 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: A brief introduction, Physical and other models, Review of basics; Uniform convergence, Fixed Point Theorem, Some points in Linear Algebra (Chapter 1, 2 of the Text book)
UNIT 2: First Order Equations, Exact Differential Equations (Chapter 3, Sections 3.1,3.2.)
UNIT 3: Second Order Linear Equations, PDE and ODE (Chapter 3, Sections 3.3-3.6.)
UNIT 4: General Theory of Initial Value Problems; Well-posed problems, Uniqueness Theorem (Chapter 4, Sections 4.1-4.2.)
UNIT 5: Existence and Uniqueness Theorems, Continuous dependance of solution on initial data and dynamics (Chapter 4, Sections 4.3-4.8.)
Text Book:

1. A. K. Nandakumaran; P. S. Datti; Raju K. George, *Ordinary Differential Equations; Principles and Applications*, Cambridge University Press, IISc Series 2017.

References:-

1. Peter J. Collins, *Differential and Integral Equations*, Oxford University Press,(2006).

2. Carmen Chicone, *Ordinary Differential Equations with Applications*, Springer (2006).

3. George F. Simmons, *Differential Equations with Applications and Historical Notes*, Tata McGraw-Hill, Third Editon 2003.

4. Michael D. Greenberg, *Ordinary Differential Equations*, Wiley (2012).

5. Michael E. Taylor, *Introduction to Differential Equations*, AMS (2011).

6. Vladimir I. Arnol'd, *Ordinary Differential Equations*, Springer (1992).

7. Earl A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications, New york, (1961).

Cochin University of Science and Technology
Department of Mathematics

Mathematics Elective Papers

(Semester: 5 and 6)

Departmental Elective

(Offered for students opting Mathematics. Students from any other department can also opt.)

Semester V or VI: MAT 10505 / MAT 10605 - Discrete Mathematics

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours
Objective: This course gives a thorough introduction to Discrete Mathematics with rigorous mathematics and serves as the basis for further studies in this area.

Outcome: After completing the course, the student will achieve a basic foundation in Discrete Mathematics.

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. Eulers Tours, the Chinese postman problem. Hamiltonian graphs and the travelling salesman problem.
Text 1: Chapter 2 (Sections 2.1, 2.2, 2.3, 2.6); Chapter 3 (Sections 3.1 (algorithm deleted), 3.2 (algorithm deleted), 3.3, and 3.4 (algorithm deleted))

Module 3: Counting
Counting, Basic counting principles, Permutations, Combinations, Pigeon-hole principle, Inclusion-exclusion principle, Ordered-unordered partitions.
Text 2: Chapter 6 (Sections 6.1-6.8)

Module 4: Language, Grammars and Machine - Lattices and Ordered Sets
Languages, Grammars, Machines languages, Regular languages, Finite state automata, Finite state machines, ordered sets, Lattices distributive lattices.
Text 2: Chapters 13 and 14 (Sections 13.1-13.7; 14.1-14.11)

Module 5: Boolean Algebra
Boolean algebra, Representation theorem, Minimal boolean expressions, Logic gates, boolean functions.
Text 2: Chapter 15 (Sections 15.1-15.11)

Semester V or VI: MAT 10506 / MAT 10606 - Linear Programming

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours
Objective: Linear Programming is perhaps the most recognized and widely used optimization tool in the world today. It has its origins in planning and operations models from World War II through the seminal work of George Dantzig and his development of the simplex method. In this course, the student will learn how to model real world problems as linear programs, and will learn various methods to solve them.

Learning Outcomes: After the completion of this course, the student should be able to:
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 Mathematics Springer (1989), Springer-Verlag, 2003.
6. R. Panneerselvam: Operations Research, PHI, New Delhi (Fifth printing), 2004.

Module 1: Mathematical Preliminaries
Euclidean Space, Linear Algebraic functions, Convex Sets. (Chapter 1 (1.1-1.19) of the text).

Module 2: : Linear Programming
Introduction Degeneracy. (Chapter 3 (3.1-3.14) of the text).

Module 3: Linear Programming (continued)
Simplex multipliers Dual simplex method. (Chapter 3 (3.15-3.20) of the text).

Module 4:
Transportation and Assignment problems. (Chapter 4 (4.1 4.15) of the text).

Module 5:
Flow and potential in networks. (Chapter 5 (5.1 5.9) of the text).

Semester V or VI: MAT 10507 / MAT 10607: Elements of Applied Mathematics

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the structure of $\mathbb{C}^n$ and it is planned to introduce the Discrete Fourier Transformation in a Linear algebraic perpsective. Towards the end Differece calculus and solution of Linear and Non Linear difference equations will be discussed.

Learning Outcomes: After the completion of this course, the student should be able to 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 New York, (1999).

2. Walter G. Kelley & Allan C. Peterson Difference Equations An Introduction with Applications, Second Edition, Academic Press 2001.

References:-

1. Stephane Mallat, *A Wavelet Tour Of Signal Processing*, Academic Press (1999).

2. Don Hong, Jianzhong Wang, Robert Gardner, *Real Analysis with an Introduction to Wavelets*, Elsevier Academic Press (2005).

3. Ronald. E.Mickens, Difference Equations: Theory, Applications and Advanced Topics, Third Edition, Chapman and Hall, 2015.

UNIT 1: Diagonalization of Linear Transformations and Matrices, Inner products, Orthonormal Bases and Unitary Matrices. (Chapter 1, Sections 1.5, 1.6 of the text 1.)

UNIT 2: The Discrete Fourier Transform, Translation-Invariant Linear Transformations (Chapter 2, Sections 2.1, 2.2 of the text 1.)

UNIT 3: The Fast Fourier Transform, Introduction, The Difference Operator, Summation, Generating Functions and Approximate summation. (Section 2.3 of text 1, Chapters 1, 2 of the text 2.)

UNIT 4: Linear Difference Equations, First Order Equations, General Results for Linear Equations, Solving Linear Equations, Applications. (Chapter 3, Sections 3.1, 3.2, 3.3, 3.4 of the text 2.)

UNIT 5: Equations with Variable Coefficients, Nonlinear Equations That Can Be Linearized, The z-Transform. (Chapter 3 sections 3.5, 3.6, 3.7 of text 1.)

Semester V or VI: MAT 10508 / MAT 10608: Introduction to Optimization Techniques

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: The objective of this course is to introduce different classes of optimization problems following some classical methods to solve them. Starting with methods to solve Linear Programming problem, different direct and indirect methods to solve Non-linear Programming problems are also discussed in this course. This course also includes solution methods for constrained and unconstrained optimization problems.

Learning Outcomes: After the completion of this course, the student should be able to
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 Optimization with Equality Constraints, Multivariable Optimization with Inequality Constraints, Convex Programming Problem. (Sec 2.1-2.6).

Module 3: Linear Programming
Standard Form of a Linear Programming Problem, Simplex Algorithm, Duality in Linear Programming, Transportation Problem, Karmarkars 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, Powells Method, Steepest Descent (Cauchy) Method, Conjugate Gradient (FletcherReeves) Method, Newtons 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, Zoutendijks Method of Feasible Directions, Rosens Gradient Projection Method, Sequential Quadratic Programming, Penalty Function Method, Convex Programming. Problem. (Sec 7.9-7.8, 7.10-7.15).

Semester V or VI: MAT 10509 / MAT 10609: Metric Topology

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: The aim is to give a very streamlined development of a course in metric space topology emphasizing only the most useful concepts, concrete spaces and geometric ideas. To encourage the geometric thinking. In this course there are large number of examples which allow us to draw pictures and develop our intuition and draw conclusions, generate ideas for proofs. To this end, this course boasts of a lot of pictures. A secondary aim is to treat this as a preparatory ground for a general topology course and arm the reader with a repertory of examples.

Outcome: After completing the course, the student is expected to become familiar with metric topology, 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, Uniform Continuity, Limit of a Function, Open and closed maps. (Chapter 3 of Text book 1).

Module 3: Compact Spaces and their Properties, Continuous Functions on Compact Spaces, Characterization of Compact Metric Spaces and Arzela-Ascoli Theorem. (Chapter 4 of Text book 1).

Module 4: Connected Spaces, Path Connected spaces. (Chapter 5 of Text book 1).

Module 5: Examples of Complete Metric Spaces, Completion of a Metric Space, Baire Category Theorem and Banach's Contraction Principle. (Chapter 6 of Text book 1).

Semester V or VI: MAT 10510 / MAT 10610: Fuzzy Mathematics

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course gives a thorough introduction to Fuzzy Mathematics with an extension to how crisp concepts can be fuzzified through introducing the concept of Fuzzy Graphs.

Outcome: 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 Publishing Company 1986.

Syllabus

Module 1: Crisp sets to Fuzzy sets
Introduction , Crisp Sets: An Overview ,Fuzzy Sets: Basic Types ,Fuzzy Sets: Basic concepts. Additional properties ofalpha cuts, Representation of fuzzy sets.
(Chapter 1: 1.1, 1.2, 1.3 and 1.4 and Chapter 2: 2.1 , 2.2 of Text 1).

Module 2: Operations on Fuzzy Sets
Types of Operations, Fuzzy complements, Fuzzy intersections: t-norms, Fuzzy Union, t-conorms, Combinations of operations.
(Theorems 3.7, 3.8,3.11,3.13, 3.16 and 3.18 statement only)
(Chapter 3: 3.1, 3.2, 3.3, 3.4, 3.5 of Text 1).

Module 3: Fuzzy Arithmetic
Compact Fuzzy numbers, Arithmetic operations on Intervals, Arithmetic operations on Fuzzy numbers. (Exclude the proof of Theorem 4.2), Fuzzy equations.
(Chapter 4: 4.1, 4.3, 4.4 and 4.6 of Text 1).

Module 4: Fuzzy Logic
Classical Logic: An Overview, Multivalued Logics, Fuzzy propositions, Fuzzy quantifiers, Linguistic Hedges, Inference from Conditional Fuzzy propositions.
(Chapter 8: 8.1, 8.2, 8.3, 8.4, 8.5 and 8.6 only of Text 1).

Module 5: Fuzzy Graphs
Fuzzy Graphs: Definitions and Basic Properties, Connectivity in Fuzzy Graphs, Forests and Trees, Fuzzy Cut Sets.
(Chapter 2: 2.1, 2.2, 2.3, 2.4 of Text 2).

Semester V or VI: MAT 10511 / MAT 10611: Introduction to Optimization in Machine Learning

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours
Objective: This course introduces relevant aspects of linear algebra and how these concepts are related to optimization in machine learning.

Outcome: After completing the course, the student is expected to become familiar with the application of Linear Algebra in Machine learning and how the concepts of linear algebra is related to optimization methods used in machine learning.

Text books:

1 Aggarwal, C. C., Aggarwal, L. F., & Lagerstrom-Fife. (2020). Linear algebra and optimization for machine learning (Vol. 156). Springer International Publishing.

Reference books:

1 Boyd, S., Boyd, S. P., & Vandenberghe, L. (2004). Convex optimization. Cambridge university press.

2 Noble, B., & Daniel, J. W. (1977). Applied linear algebra (Vol. 477). Englewood Cliffs, NJ: Prentice-Hall

3 Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. MIT press

4 Strang, G. (2019). Linear algebra and learning from data (Vol. 4). Cambridge: Wellesley-Cambridge Press.

5 Strang, G. (2016). Introduction to Linear Algebra (5th Edition). Wellesley Publishers (India), ISBN : 978-09802327-7-6.

Syllabus

Module 1: Introduction to Optimization, Scalars, Vectors and Matrices, Matrix Multiplication on Decomposible Operator, Matrix Factorization.
(Sections 1.1- 1.3, 1.4.1 of Text 1).

Module 2: Basic Problems in Machine Learning- Clustering, classification and Regression Modelling, Outlier Detection, Optimization for Machine Learning
(Sections 1.4-1.5 of Text 1).

Module 3: Geometry of Matrix Multiplication, Vector Spaces and their Geometry, Basis, Rank of a Matrix, Effect of Matrix Operations on Rank, Generating Orthogonal Basis sets
(Sections 2.1- 2.3, 2.6-2.7 of Text 1)

Module 4: An Optimization- centric view of Linear Systems, Determinants, Diagonalizable transformations and Eigenvectors, Fast Matrix Operations in Machine Learning, Diagonalizable matrices in Machine Learning
(Sections 2.8, 3.2-3.3, 3.4.1- 3.4.2 of Text 1).

Module 5: Symmetric Matrices in Quadratic Optimization, Variable Separation for Optimization, Numerical Algorithms for Finding Eigen vectors, Basics of Optimization
(Sections 3.4.3- 3.4.5, 3.5, 4.2 of Text 1).

Semester V or VI: MAT 10512 / MAT 10612: Elementary Number Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours
Objective: Number theory is one of the oldest and most mysterious parts of mathematics.

This course will give an introduction to the area of Number Theory.

Outcome: After completing the course, students will be equipped with the understanding of the fundamental concepts of Number theory and its application.

Prerequisites: Basic familiarity with formulas, techniques of differential and integral calculus, Natural Numbers and Integers.
Text books:

1 D. M. Burton, Elementary Number Theory, 7th Ed., McGraw Hill, 2017.

Reference books:

1 I. Niven, S. Zuckerman and H. L. Montgomery, An Introduction to the Theory of Numbers, 5th Ed., Wiley-India, 1991.

2 K. H. Rosen, Elementary Number Theory and its Applications, Pearson, 2015.

3 G. A. Jones and J. M. Jones, Elementary Number Theory, Springer-Verlag (1998).

Syllabus

Module 1. Mathematical Induction, The Binomial Theorem, Early Number theory, The Division Algorithm, The Greatest Common Divisor, The Euclidean Algorithm, The Diophantine Equation. (Chapter 1 and 2 of Text book 1).

Module 2. The Fundamental Theorem of Arithmetic, The Sieve of Eratosthenes, The Goldbach Conjecture. (Chapter 3 of Text book 1).

Module 3. Carl Friedrich Gauss, Basic Properties of Congruence, Binary and Decimal Representations of Integers, Linear Congruence and the Chinese Remainder Theorem. (Chapter 4 of Text book 1).

Module 4. Pierre de Fermat, Fermat's Little Theorem, Pesudoprimes, Wilson's Theorem, The Fermat-Kraitchik Factorization Method. (Chapter 5 of Text book 1).

Module 5. Euler's Criterion, The Legendre symbols and Its Properties, Quadratic Reciprocity, Quadratic Congruence with Composite Moduli. (Chapter 9 of Text book 1).

Cochin University of Science and Technology
Department of Mathematics

Mathematics Core Papers

(Semester: 7 - 10)

Departmental Core

(Offered for students opting Mathematics. Students from other department may also opt.)

Semester VII
MAT 10701 - Linear Algebra

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the notion of vector spaces. Finite-dimensional vector spaces and maps between them preserving the structure are objects of study. The dual of a vector space also forms a major part of the study, especially with the study of the adjoint map. Studying the important multi-linear maps, like the Determinant map, form an important part of the course. Finally, the important primary decompositions of the vector space concerning a linear transformation is studied. This also helps to understand the extra symmetry in the representation of the matrices.
Learning Outcomes: After the completion of this course, the student should be able to

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).

Semester VII
MAT 10702 - Real Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the structure of Real Numbers. This course is planned to introduce the notions Metric Spaces, Continuity, Uniform continuity, Differentiation, Riemann-Steiltjes integration, Fundamental theorem of Calculus, Convergence of sequence of functions, Uniform convergence, Stone-Weierstrass Theorem and Power series.
Learning Outcomes: 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 continuity, Uniform convergence and integration, Uniform convergence and differentiation. (Chapter 7, sections upto 7.18)
UNIT 5: Equicontinuous families of functions, Stone-Weierstrass Theorem, Power series. (Chapter 7; sections upto 7.18-7.33, Chapter 8; sections up to 8.5)

Text Book: Walter Rudin, Principles of Mathematical analysis, 3rd edition, McGraw-Hill Higher Education (1976).

References:-

1. Terence Tao, Analysis I and II, Third Edition, Springer 2016.
2. N.L Carothers, Real Analysis, Wiley 2000.
3. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).
4. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).
5. A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).
6. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).
7. S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)
8. K. A. Ross, Elementary Analysis; Theory of Calculus, Springer-Verlag,(2013).

Semester VII
MAT 10703 - Measure and Integration

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: One of the objectives of measure theory is to make platform for developing tools for a new method of integration of functions that are not Riemann integrable. Apart from studying the Lebesgue measure and integration, this course introduces the concept of general measure spaces and the integration in this setting also.
Learning Outcomes: After the completion of this course, the student should be able to

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, Characterizations of Riemann and Lebesgue integrability, Differentiation of monotone functions, Lebesgue's theorem, Functions of bounded variations: Jordan's Theorem (avoid proofs of Vitali Covering lemma and Lebesgue's theorem). (Section 4.4-4.5, 5.2-5.3 and 6.1-6.3 of the text)
UNIT 4: Differentiation of an integral, Absolute continuity, Convex Functions, The L^p spaces, Minkowski and Hölder inequalities, (Section 6.4-6.6 and 7.1-7.2 of the text)
UNIT 5: Completeness of L^p spaces, Approximation and Separability, The Riesz Representation for the Dual of L^p spaces (Section 7.3-7.4 and 8.1 of the text)

Text Book: H L Royden, P. M. Fitzpatrick, Real Analysis, Fourth Edition (2009), PHI

References:-

1. I K Rana, An Introduction to Measure and Integration, Narosa Publishing Company.
2. P R Halmos, Measure Theory, GTM , Springer Verlag.
3. T.W. Gamelin, Complex Analysis, Springer.
4. R.G. Bartle, The elements of Integration (1966) John Wiley & Sons, Delhi,(2006)
5. K B. Athreya and S N Lahiri:,Measure theory, Hindustan Book Agency, New Delhi.
6. Thamban Nair, Measure and Integration: A First Course, CRC Press, 2019.
7. Terence Tao: An Introduction to Measure Theory,Graduate Studies in Mathematics,Vol 126 AMS.
8. S. Kesavan Measure and Integration, Hindustan Book Agency, Springer (TRIM 77).

Semester VII
MAT 10704 - Groups and Rings

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the basic algebraic structure Group, and studies various aspects of groups. It also covers another mathematical structure Rings and various types of rings.

Learning Outcomes: After the completion of this course, the student should be able to

1. have a working knowledge of the concepts such as definition of a group, order of a finite group and order of an element.
2. 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
3. will be able to understand the mathematical concepts such as permutation groups, factor groups, group homomorphisms etc.
4. will have knowledge on advanced topics such as Sylows theorem and should be able to apply this result.
5. 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, Group Actions; Subgroups: Definitions and Examples, Centralizers and Normalizers, Stabilizers and Kernels (Chapter 1 and Chapter 2 sections 2.1, 2.2 of Textbook)

UNIT 2: Subgroups: Cyclic groups, Groups generated by subsets of a Group, The Lattice of Subgroups of a Group. Quotient Groups and Homomorphisms: Quotient Groups, homomorphisms, Langanges Theorem, The Isomorphism Theorems, Composition Series and Holder Program, Transpositions and Alternating Group. (Chapter 2 sections 2.3-2.5 and Chapter 3 of Textbook sections 3.1-3.5)

UNIT 3: Group Actions: Group actions and permutation representations, Cayleys Theorem, Orbits, Counting Lemma, Class Equation, Automorphisms, Sylow Theorems, Simplicity of A_n. (Chapter 4 of Textbook sections 4.1-4.6)

UNIT 4: Rings: Basic Definitions and Examples, Examples: Polynomial Rings, Matrix Rings, and Group Rings, Ring Homomorphisms an Quotient Rings, Properties of Ideals. (Chapter 7 of Textbook sections 7.1 - 7.4).

UNIT 5: Factorization in domains: Euclidean Domains, Principal Ideal Domains (P.I.D.s), Unique Factorization Domain. (Chapter 8 of Textbook sections 8.1, 8.2, 8.3)

Text Books:

1. Abstract Algebra - D.S. Dummit and R.M. Foote, 3rd Edition, Publisher: Wiley.

References:-

1. A First Course in Abstract Algebra - J.B. Fraleigh, 7th Edition, Publisher - Pearson
2. Algebra - M. Artin, Second Edition, Publisher - Pearson

3. Contemporary Abstract Algebra - J. A. Gallian, 4th Edition, Publisher - Narosa
4. Topics in Algebra - I.N. Herstein, Second Edition, Publisher - Wiley Student Edition.
5. Rings and Modules - C. Musili, Second revised edition, Narosa Publishing House.

Semester VII
MAT 10705 - Topology I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: Topology is essentially the study of surfaces in which normally non geometric properties are studied. This course introduces the basic concepts of topology and standard properties such as compactness connectedness, separation axioms.
Learning Outcomes: On completion of this course, the student should be able to

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 Urysohns Metrization Theorem. (Relevant sections of Chapter 8 & 9 of Text 1)

Text Book: K.D. Joshi: Introduction to General Topology (Revised Edn.), New Age International (P) Ltd., New Delhi, Revised printing in 1984.

References:-

1. G.F. Simmons: Introduction to Topology and Modern Analysis; McGraw-Hill International Student Edn.; 1963
2. J. Dugundji: Topology; Prentice Hall of India; 1975
3. J. R. Munkers; Topology (Second Edition) PHI, 2009.
4. M. Gemignani: Elementary Topology; Addison Wesley Pub Co Reading Mass; 1971
5. M.A. Armstrong: Basic Topology; Springer- Verlag New York; 1983
6. M.G. Murdeshwar: General Topology (2nd Edn.); Wiley Eastern Ltd; 1990
7. S. Willard: General Topology; Addison Wesley Pub Co., Reading Mass; 1976
8. John Gilbert Hocking and Gail S. Young, Topology (Revised Edition), Dover Publications, (1988).

Semester VIII
MAT 10801 - Fields and Modules

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the advanced topics in Group theory. It also covers other mathematical structures Modules and Fields.
Learning Outcomes: After the completion of this course, the student should be able to

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 PIDs.
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

Semester VIII
MAT 10802 - Functional Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This is the first part of the series of 2 courses taught in the second and third semester on Functional Analysis. In the first part, we cover important structures used in analysis like Banach spaces, Hilbert spaces and operators acting on them. The foundation results are discussed in this part.
Learning Outcomes: After the completion of this course, the student should be able to 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).

Semester VIII
MAT 10803 - Complex Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of complex functions which will be followed by the Classical theory of analytic functions. This will involve some of the classical theorems in the subject such as Cauchys 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: Cauchys Theorem and Integral Formula, The homotopic version of Cauchys Theorem and simple connectivity, Counting zeros; the Open Mapping Theorem and Goursats 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, Schwarzs Lemma, Convex functions and Hadamards Three Circles Theorem and Phragmen-Lindelof Theorem [Chapter - VI (Sections - 1,2,3,4)].

Text Book: J.B. Conway, Functions of One Complex Variable (2^{nd} Edition), Springer 1973.

References:-

1. L.V. Ahlfors, Complex Analysis (Third Edition) Mc-Graw Hill International (1979)

2. Milnor, Dynamics in One Complex Variable (3rd ed.), Princeton U. Press.

3. T.W. Gamelin, Complex Analysis, Springer

4. H. A. Priestley: Introduction to Complex Analysis, Oxford University Press.

5. J.H. Mathews and R.W. Howell: Complex Analysis for Mathematics and Engineering, Jones & Bartlett Learning.

Semester VIII
MAT 10804 - Functions of Several Variables and Geometry

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: In the first module, the students will be introduced to 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 manifolds are studied.
5. Riemannian structure on a differentiable manifold is introduced which makes the study of geometry on regular surfaces in $\mathbb{R}^3$ more clear conceptually.
6. Special emphasis is laid on the study of the Gauss map culminating with the Gaussian curvature for regular surfaces in $\mathbb{R}^3$. Gauss-Bonnet theorem and its applications are studied in details.
7. Other important geometric concepts that are studied include the first fundamental form, parallel 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, (Differentiation 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.

Semester VIII
MAT 10805 - Computational Mathematics Laboratory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of Numerical methods for differentiation and integration, and simple models of Partial differential equations. This course is planned to introduce the basics of mathematical documention setting using LaTeX. Introduction of programming using Python for solving Mathematical problems arising in various fields, that are covered in the Msc curriculum.

Learning Outcomes: After the completion of this course, the student should be able to Be familiar 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 displays (Texts 1, 2)

UNIT 2: Introduction to programming with Python, Fundamentals, Data types, Functions, Pointers and string handling, Class, File handling, Programming Excercises from Linear Algebra, Number Theory, Numerical Approximations, Differential Equations. (Texts 3, 4, 5 , 6)

UNIT 3: Matplotlib, Numpy, and Scipy Exercises. (Texts 7, 3)

UNIT 4: Introduction to SageMath, Symbolic Calculus, Linear Algebra using SageMath, SageTex Package, Graphics, Combinatorics, Graph Theory (Text 8).

UNIT 5: Coding Theory using SageMath, Standard Rings and Fields (Text 8)

References:-

1. George *Grätzer*, *Math into LaTeX an Introduction to LaTeX and AMS-LaTeX*, Birkhauser Boston, (1996).

2. Donald. E. Knuth, *Computers & Type setting*, Addison-Wesley, (1986).

3. Hans Petter Langtangen, *A Primer on Scientific Programming with Python*, Third Edition, Springer (2012).

4. John M. Zelle, *Python Programming: An Introduction to Computer Science*, (2002).

5. Steven Lott, *Functional Python Programming*, Packt Publishing Ltd, (2015).

6. Jody. S. Ginther Start here: Python programming made simple for the Beginner.

7. John Hunter, Darren Dale, Eric Firing, Michael Droettboom, *Matplotlib Release 1.4.3*.

8. William Stein, *SAGE Reference Manual Release 2007.10.29*.

NB: A Lab Report type-setted in LaTeX by the student has to be submitted at the end of the semester.

Semester IX
MAT 10901 - Operator Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This is the second part of the series of 2 courses taught in the second and third semester on Functional Analysis. In the second part, we focus on compact operators on Banach spaces, Hilbert spaces and their spectral properties.
Learning Outcomes: After the completion of this course, the student should be able to 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 Problems. (Chapter VII, Section 28, Appendix C).

Text Book: Balmohan V. Limaye, *Functional Analysis*, Revised Second Edition, New Age International Publishers, 1996 (Reprint 2013)

References:-

1. Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).
2. Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).
3. E. Kreyzig, Introduction to Function Analysis with Applications, Addison Wesley.
4. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).
5. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).
6. Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork (1975).
7. Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi(2009).
8. G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.
9. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd (2001).

Semester IX
MAT 10902 - Ordinary Differential Equations & Integral Equations

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of Ordinary differential equations. Course aims to build an understanding of the classical models in terms of ordinary differential equations and pave the foundations for the study of Integral equations.
Learning Outcomes: 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, Gausss Hyper Geometric Equation. (Chapter 4, Section 24, 25. Chapter 5, sections 27, 28, 29, 30, 31.)
UNIT 2: Legendre Polynomials, Properties of Legendre Polynomials, Bessel Polynomials, Properties of Bessel Polynomials. (Chapter 8, sections 44, 45, 46, 47.)
UNIT 3: Systems, Nonlinear equations: Autonomous systems, The Phase Plane and its Phenomena, Types of Critical points. Stability, Critical points and Stability for Linear Systems. (Review Chapter 10, Chapter 11, Sections 58, 59,60)
UNIT 4: Method of successive approximations, Picard's Theorem, Integral Equations with separable kernels, Fredholm Integral Equations, Method of successive approximations. (Chapter 13, sections 68, 69 of text 1, Chapter 2 and 3 of the text 2.)
UNIT 5: The Fredholm Method of Solution, Fredholm's Theorems, Applications to Ordinary Differential Equations. (Chapters 4, 5 of the text 2)
Text Books:

1. George F. Simmons, *Differential Equations with Applications and Historical Notes*, Tata McGraw-Hill, Third Editon 2003.

2. Ram P. Kanwal, *Linear Integral Equations*, Second Edition, Springer Science+Business Media, LLC, (1997).

References:-

1. Peter J. Collins, *Differential and Integral Equations*, Oxford University Press,(2006).

2. Carmen Chicone, *Ordinary Differential Equations with Applications*, Springer (2006).

3. Linear Integral Equations

4. Michael D. Greenberg, *Ordinary Differential Equations*, Wiley (2012).

5. Michael E. Taylor, *Introduction to Differential Equations*, AMS (2011).

6. Vladimir I. Arnol'd, *Ordinary Differential Equations*, Springer (1992).

7. Earl A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications, New york, (1961).

Semester X
MAT 11001 - Partial Differential Equations and Variational Calculus

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with simple models of Partial differential equations which will be followed by the analytic and algebraic study of PDEs. This will involve some of the classical models in the subject: diffusion equations and wave equations. Towards the end of the course students will get an idea of variational calculus.
Learning Outcomes: After the completion of this course, the student should be able to 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, Eulers method of finite differences, Ritz method. (Chapter 3, 4, 5 of text 2).

Text 1. Tyn Myint-U, Lokenath Debnath *Linear Partial Differential Equations for scientists and Engineers*, Fourth Edition, Birkhauser (2007).

Text 2. Lev D. Elsgolc, *Calculus of Variations*, Dover publications, Inc. (2007.)

References:-

1. Walter A. Strauss, *Partial Differential Equations an Introduction*, John Wiley, (1992).
2. Ravi P. Agarwal, Donal O'Regan, *Ordinary and Partial Differential Equations With Special Functions, Fourier Series, and Boundary Value Problems*, Springer-Verlag (2009).
3. Fritz. John, *Partial Differential Equations*, Fourth Edition, Springer (2009).
4. G. Evans, I. Blackedge and P.Yardley, *Analytic Methods for Partial Differential Equations*, Springer (1999).
5. Ian N. Sneddon, *Elements of Partial Differential Equations*, McGraw Hill (1983).

Semester IX
MAT 11002 - Probability Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the introduction to probability theory following different probability distributions. The connection between probability theory and measures are also discussed in this course. This will involve some of the classical theorems in the subject such as central limit theorem and law of large numbers.
Learning Outcomes: After the completion of this course, the student should be able to

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 conditioning, Discrete random variables, The branching process, Borels strong law of large numbers (Chapter 1)
UNIT 2: Integration: Measurability and measure, The Lebesgue integral, The other big theorems (Chapter 2)
UNIT 3: Probability and Expectation: From integral to expectation, Gaussian vectors, Conditional expectation (Chapter 3)
UNIT 4: Convergences Almost-sure convergences, Two other types of convergence, Zero-one laws (Chapter 4, section 4.1-4.3)
UNIT 5: Convergence continued: Convergence in distribution and in variation, Central Limit Theorem, The hierarchy of convergences (Chapter 4, section 4.4-4.6)

Text. Pierre Bremaud, Probability Theory and Stochastic Processes, Springer 2020.

References:-

1. S.R. Athreya, V.S. Sunder: Measure and Probability, University Press (India) Pvt. Ltd. (2008).
2. Sidney I Resnick: A Probability Path, Birkhauser 2005 Edition
3. A.K. Basu: Probability Theory, Prentice Hall, India, 2002.
4. W. Feller: An Introduction to Probability Theory and Its Applications.

Cochin University of Science and Technology
Department of Mathematics

Mathematics Elective Papers

(Semester: 9 and 10)

Departmental / Interdepartmental Elective

(Offered for students opting Mathematics. Students from other department can also opt.)

Semester IX
MAT 10905 : Topics in Applied Mathematics
(Inter-departmental elective. Not for students opting Mathematics)

Number of credits: 3
Number of hours per week: 4 hrs
Total No. of Hours: 72 hours

Objective: To Learn important Mathematical Tools applicable in Science and Technology.
Learning Outcomes: After the completion of this course, the student should able to 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 Derivatives and Integrals ODEs, Unit Step Function (Heaviside Function), Second Shifting Theorem (t-Shifting)
UNIT 3: Fourier Series, Arbitrary Period, Even and Odd Functions, Half-Range Expansions, Forced Oscillations, Fourier Integral, Fourier Cosine and Sine Transforms, Fourier Transform.
UNIT 4: Basic Concepts of PDEs, Modeling: Vibrating String, Wave Equation, Modeling: Heat Flow from a Body in Space, Heat Equation
UNIT 5: Complex Numbers: Preliminary requirements, limits, Continuity, Cauchy-Reimann equations, Complex Integration, Line Integral in the complex plane, Cauchy's Integral Theorem, Cauchy's Integral formula, Derivatives of Analytic functions, Laurent Series, Singularities and zeros, Residue Integration method, Residue Integration of real Integrals.

Text Book: Advanced Engineering Mathematics, Erwin Kreyszig, 10^{th} edition, JOHN WILEY & SONS, INC.2011. (Chapter 2, Section 2.1-2.3, and 2.5, Chapter 6, Section 6.1-6.4, Chapter 11, Section 11.1-11.3, 11.7,11.8, Chapter 12, Section 12.1-12.6, Chapter 14, Section 14.1-14.4, Chapter 16, Section 16.1-16.4.)

References:-

1. Advanced Engineering Mathematics, C.Ray Wylie, Louis. C. Barrett, 6th edition, McGraw Hill Publishing, 1998.
2. Advanced Engineering Mathematics, K.A Stroud, 5th edition, Palgrave Macmillain, 2003.
3. Advanced Engineering Mathematics, Michael Greenberg, 2nd edition, Prentice Hall, 1998.
4. Advanced Engineering Mathematics, Dennis. G.Zill, Warren S.Wright, 4th edition, 2011.

Semester IX or X
MAT 10906/ MAT 11006 : Advanced Linear Algebra

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of linear algebra, which will be followed by the factorisation and triangulation theorems. This will also discuss canonical forms and eigenvalue inequalities and inclusions for hermitian matrices. Some important results in linear algebra are discussed here which are not done in the core courses on this subject. This will benefit students wants to pursue research in the areas like Functional Analysis, Spectral theory, Stochastic models, Numerical linear algebra, etc.
Learning Outcomes: After the completion of this course, the students will be 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).

Semester IX or X
MAT 10907/ MAT 11007: Discrete Framelets

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: Course is aimed to introduce the basic tools for applications using Discrete Framelets. Students will get knowlege in analysing signals and images using finite filters. This course will pave the necessary foundations to study numerical solutions of partial differential equations and some insights into computer aided geometric design.
Learning Outcomes: After the completion of this course, the student should be able to

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 Transforms, Some Examples of Wavelet or Framelet Filter Banks. (Section 1.1 of text.)
UNIT 2: Sparsity of Discrete Framelet transforms, Convolution and Transition Operators on Polynomial Spaces, Subdivision Operator on Polynomial Spaces, Linear-Phase Moments and Symmetry Property of Filters, An Example. (Section 1.2 of text.)
UNIT 3: Multilevel Discrete Framelet Transforms and Stability, Multilevel Discrete Framelet Transforms, Stability of Multilevel Discrete Framelet Transforms, Discrete Affine Systems in $\ell^2(\mathbb{Z})$, Nonstationary and Undecimated Discrete Framelet Transforms (Section 1.3 of text.)
UNIT 4: Oblique extension principle, OEP-Based Tight Framelet Filter Banks, OEP-Based Filter Banks with One Pair of High-Pass Filters, OEP-Based Multilevel Discrete Framelet Transforms. (Section 1.4 of text.)
UNIT 5: Discrete Framelet Transforms for signals on bounded Intervals, Boundary Effect in a Standard Discrete Framelet Transform, Discrete Framelet Transforms Using Periodic Extension, Discrete Framelet Transforms Using Symmetric Extension, Symmetric Extension for Filter Banks Without Symmetry, Discrete Framelet Transforms Implemented in the Frequency Domain. (Section 1.5 and 1.6 of text.)

Text. Bin Han, Framelets and Wavelets Algorithms, Analysis and Applications, Birkhauser 2017.

References:-

1. Ole Christensen, Frames and Bases An Introductory Course, Birkhauser, 2008.
2. Ole Christensen, Frames and Riesz Bases, Birkhauser, 2008.
3. Christopher Heil, A Basis Theory Primer, Citeseer, 1998.
4. Yves Meyer, Wavelets and Operators, CUP, England, 1992.
5. Ingrid Daubechies, Ten Lectures on Wavelets, SIAM, Philadelphia, 1992.

Semester IX or X
MAT 10908/ MAT 11008 : Harmonic Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of Measure theory. This course is planned to introduce the basics of Topolgical groups and measure and Intergration on Locally compact groups.
Learning Outcomes: After the completion of this course, the student should be able to 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 Compact Groups. (Sections 5.1, 5.2, 5.3, 5.4, 5.5)
Text Book: Folland, G.B., *A Course in Abstract Harmonic Analysis*, CRC Press, (1995).

References:-

1. Hewitt, E and Ross K., *Abstract Harmonic Analysis* Vol.1 Springer (1979).

2. Gaal, S.A., *Linear Analysis and Representation Theory*, Dover (2010).

3. Asim O. Barut and Ryszard Raczka, *Theory of Group Representations*, second revised edition, Polish scientific publishers (1980).

4. Groenchenig, K., *Foundations of time frequency analysis*, Birkhauser Boston (2001).

Semester IX or X
MAT 10909/ MAT 11009 : Integral Transforms

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with Fourier Transforms in detail. This course is planned to introduce the basics of Integral Transforms and its applications in various fields.
Learning Outcomes: After the completion of this course, the student should be able to 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, 2.5 and Chapter 12)
UNIT 2: Poisson's Summation formula, The Shannon Sampling Theorem, Gibbs Phenomenon, Heisenbergs' Uncertainty Principle, Applications of Fourier Transform to ODE, Laplace Transforms and their basic properties. (Sections 2.6, 2.7, 2.8, 2.9, 2.10, 3.1, 3.2, 3.3, 3.4)
UNIT 3: Convolution Theorem and the properties of convolution, Differentiation and Integration of Laplace transforms, The Inverse Laplace Transforms, Tauberian theorems and Watson's Lemma, Applications of Laplace transforms, Evaluation of Definite Integrals, Applications of Joint Laplace and Fourier Transform. (Sections 3.5, 3.6, 3.7, 3.8, 3.9, 4.1, 4.2, 4.3, 4.6, 4.8)
UNIT 4: Finite Fourier Sine and Cosine transforms, Basic properties and Applications, Finite Lapace Transforms, Tauberian Theorems. (Chapter 10, 11)
UNIT 5: Hilbert Transform and its basic properties, Hilbert transform in the complex plane, applications of Hilbert Transform, Asymptotic expansion of One sided Hilbert Transform. (Sections 9.1, 9.2, 9.3, 9.4, 9.5, 9.6)
Text Book: Lokenath Debnath, Dambaru Bhatta *Integral Transforms and their Applications*, second edition, Taylor and Francis, (2007).

References:-

1. Frederick W. King, *Hilbert Transforms*, CRC (2009).
2. Larry C. Andrews, Bhimsen K. Shivmaoggi *Integral Transforms for Engineers*, (1999).
3. Ian N. Sneddon, *The Fourier Transforms*, Dover Publishers (1995).
4. Joel L.Schiff, *Laplace Transforms: Theory and Applications*, second revised edition, Springer (1980).
5. B.Davies, *The Integral Transforms and their applications*, Springer-Verlag (1978).
6. Ian N. Sneddon, *The Use of Integral Transforms*, McGraw-Hill (1972).

Semester IX or X
MAT 10910/ MAT 11010 : Functions of Several Variables

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the structure of $\mathbb{R}^n$. This course is planned to introduce the Differential calculus on the finite dimensional Euclidean Space and Integration on $\mathbb{R}^n$.
Learning Outcomes: After the completion of this course, the student should be able to be familiar with Differentiation and Intgration on $\mathbb{R}^n$.
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 $\mathbb{R}^n$ to $\mathbb{R}$ (Chapter 12)
UNIT 2: Implicit Functions and Extremum problems, functions with nonzero Jacobian determinant, Inverse function theorem, Implicit funtion theorem, Extrema of real-valued functions of several variables, Extremum problems with side conditions(Chapter 13)
UNIT 3: Multiple Riemann Integrals, The measure of a bounded interval in $\mathbb{R}^n$, Riemann Integral of a bounded funtion on a compact interval in $\mathbb{R}^n$, Lebesgue criterion for the existence of a multiple Riemann integral. (Chapter 14, Sections 14.1, 14.2, 14.3, 14.4, 14.5)
UNIT 4: Jordan Measurable sets in $\mathbb{R}^n$, Multiple Integration over Jordan-measurable sets, Step functions and their integrals, Fubini's reduction thorem for the double integral of a step function. (Chapter 14, 15 Sections 14.6, 14.7, 14.8, 14.9, 14.10, 15.1,15.2,15.3,15.4, 15.5)
UNIT 5: Multiple Lebesgue Integrals, Fubini's reduction theorem for double integrals ,Tonelli-Hobson test for integrability The transformation formula for multiple integrals(Chapter 15, Sections 15.6, 15.7, 15.7, 15.8, 15.9, 15.10, 15.11, 15.12, 15.13)
Text Book: Tom M. Apostol, *Mathematical Analysis*, Second Edition, Addison-Wesley 1974.

References:-

1. Serge Lang, *Calculus Of Several Variables*, Addison-Wesley Publications, (1973).

2. C.H. Edwards Jr.,*Advanced Calculus of Several Variables*, Academic Press New York, (1973).

3. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, New York (1986).

4. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, New York (1991).

5. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London, (1996).

6. K. A. Ross, Elementary Analysis; Theory of Calculus, Springer-Verlag, 2013.

Semester IX or X
MAT 10911/ MAT 11011 : Advanced Spectral Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of Spectral Theory of Linear Operators in Normed Spaces. The idea of this course is to cover various classifications of spectrum and finally present the spectral theorem for bounded self-adjoint operators. Applications to quantum mechanics is also done.
Learning Outcomes: After the completion of this course, the student should be able to 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, Hindusthan Book Agency, New Delhi (2009).
7. G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.
8. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd. (2001).

Semester IX or X
MAT 10912/ MAT 11012 : Banach Algebra and Spectral Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course introduces the notion of Banach Algebras. The theory of commutative Banach algebras are discussed in detail. Also, the spectral theory of bounded and unbounded operators on Hilbert spaces are discussed.
Learning Outcome: After completing the course, the student is expected to 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, Involutions, Positive functionals. (Chapter 11 of Text Book)
UNIT 3: Bounded Operators on a Hilbert Space: A commutativity theorem, Resolutions of the identity, The spectral theorem, Positive operators, An ergodic theorem. (Chapter 12 of Text Book)
UNIT 4: Unbounded Operators: Symmetric operators, The Cayley transform, Resolutions of the identity. (Chapter 13 of Text Book)
UNIT 5: Unbounded Operators (Contd.): The Spectral Theorem, Semigroup of Operators. (Chapter 13 of Text Book)

Text Book: Rudin, Walter. Functional Analysis. Second Edition. International Series in Pure and Applied Mathematics. McGraw-Hill, Inc., New York, 1991.

References:-

1. Takesaki, M. Theory of Operator Algebras I. Reprint of the first (1979) edition. Encyclopaedia of Mathematical Sciences, 124. Operator Algebras and Non-commutative Geometry, 5. Springer- Verlag, Berlin, 2002.

2. Arveson, William. An Invitation to C*-algebras. Graduate Texts in Mathematics, No. 39. Springer-Verlag, New York-Heidelberg, 1976.

3. Douglas, Ronald G. Banach Algebras Techniques in Operator Theory. Second Edition. Graduate Texts in Mathematics, 179. Springer-Verlag, New York, 1998.

Semester IX or X
MAT 10913/ MAT 11013 : Number Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of theory of numbers which will be followed by the divisibility and prime. This will involve some of the classical theory in the subject such as congruences, the Chinese remainder theorem, quadratic reciprocity law, Arithmetic functions and diophantine equations.
Learning Outcomes: After the completion of this course, the student should be able to be familiar 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 Eastern, (1972).

2. A. Baker, A Concise Introduction to the Theory of Numbers, Cambridge University Press, Cambridge, (1984).

3. K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, 2nd ed., Springer-Verlag, Berlin, (1990).

4. T.M. Apostol, An Introduction to Analytic Number Theory, Springer-Verlag, (1976).

Semester IX or X
MAT 10914/ MAT 11014 : Representation Theory of Finite Groups

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: To introduce the facinating theory of representations to the learner. Group representation theory will be discussed in detail through FG- Modules. To discuss the irreducible representations which are the building blocks of representations in detail. Chacter of a representation is a beautiful idea which is playing a vital role in the study of representations, here we discuss the character table of a group in detrail and construct the character table which will in fact replace the group itself.
Learning Outcome: 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.

Semester IX or X
MAT 10915/ MAT 11015 : Algebraic Topology

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: At the end of the course the students will have the necessary introduction to the subject of Algebraic topology. The algebraic notions of the fundamental group of a space and that of homology and even cohomology theories is covered in the course. All the important topological constructions and concepts conducive for the algebraic study are also studied with enough examples.

Learning Outcomes: At the completion of the course, students will be comfortable with the necessary topological concepts and constructions like attaching spaces, suspension, excision, homotopy and deformation retraction among others. Along with the study of the fundamental group and classification 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, Exact sequences and excision, Equivalence of simplicial and singular homology. (Chapter 2 of Hatcher)

UNIT 4: Cellular homology (with special emphasis on CW-complexes), Mayer-Vietoris sequences, Homology with coefficients, the formal viewpoint of homology theories (briefly) (Chapter 2 of Hatcher)

UNIT 5: The definition of cohomology groups, The Universal Coefficient theorem, computation of cohomology of spaces, Relative groups and the long exact sequence of a pair of spaces (X, A), Cup product and the Cohomology ring structure, Kunneth formula for product of spaces, Poincare duality. (Chapter 3 of Hatcher)

Text Book: Algebraic Topology, Allen Hatcher.

References:-

1. Lecture notes in Algebraic Topology, James F. Davis, Paul Kirk.

Semester IX or X
MAT 10916/ MAT 11016 : Differential Geometry

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: The course is aimed to introduce the popular tools to perform a study of geometry with the help of calculus on an n-dimensional surface. Develop the notion of curvature of parametric surfaces with the idea of, vector fields along a parametrized curve on the surface. Towards the end of the course, students will get all the necessary foundations to study Riemannian Geometry.

Learning Outcomes: After the completion of this course, the student should be able to

1. be familiar with the concepts vector fields, tangent space, surfaces and its orientations.
2. get introduced to the spherical image of surfaces, geodesics, Weingarten map, and curvature of surfaces.
3. understand local equivalence of surfaces and parametrized surfaces.
4. 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.

Semester IX or X
MAT 10917/ MAT 11017 : Algebraic Graph Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course aims to introduce students to the interconnection between Algebra and Graph Theory.

Outcome: After completing the course, the student is expected to become familiar to apply graph theoretic techniques in algebra and vice-versa.

Prerequisites: Basic knowledge of Algebra and Graph Theory

Text books:

1 C. Godsil and G. Royle: Algebraic Graph Theory, Springer, 2001.

Reference books:

1 R. B. Bapat: Graphs and Matrices, Springer, 2014.

2 N. Biggs: Algebraic Graph Theory (2nd edn.), Cambridge, 1993.

Syllabus

Module 1: Review of Graphs: Graphs, Subgraphs, Automorphisms, Homomorphisms, Circulant Graphs, Johnson Graphs, Line Graphs, Planar Graphs
(Section 1.1 - 1.8 of Text Book 1).

Module 2: Review of Groups: Permutation Groups, Counting, Asymmetric Graphs, Orbits on Paths, Primitivity, Connectivity
(Section 2.1 - 2.6 of Text Book 1).

Module 3: Transitive Graphs: Vertex transitive graphs, Edge transitive graphs, Edge connectivity, Vertex connectivity, Matchings
(Section 3.1 - 3.5 of Text Book 1).

Module 4: Matrix Theory: Adjacency matrix, Incidence matrix, Incidence matrix of oriented graphs, Symmetric matrices
(Section 8.1 - 8.4 of Text Book 1).

Module 5: Strongly Regular Graphs: Parameters, Eigen values, Some characterizations, Latin square graphs
(Section 26, 27 of Text Book 1).

Semester IX or X
MAT 10918/ MAT 11018 : Wavelets

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the structure of $\mathbb{C}^n$. This course is planned to introduce the Wavelets as an extension to the idea of Fourier's method in Linear algebraic perpsective.
Learning Outcomes: After the completion of this course, the student should be able to 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 $\mathbb{Z}_N$ (Chapter 2, Chapter 3, Sections 2.1, 2.2, 3.1)
UNIT 2: Construction of Wavelets on $\mathbb{Z}_N$: Iteration step, Examples and Applications, $l^2(\mathbb{Z})$ (Chapter 3, Sections 3.2, 3.3, Chapter 4, Section 4.1)
UNIT 3: Complete Orthonormal Sets in Hilbert Spaces, $L^2([-\pi,\pi))$ and Fourier Series, The Fourier Transform and Convolution on $l^2(\mathbb{Z})$ (Chapter 4, Sections 4.2, 4.3, 4.4, 4.5)
UNIT 4: First-Stage Wavelets on $\mathbb{Z}$, The Iteration step for Wavelets on $\mathbb{Z}$, Implementation and Examples. (Chapter 4, Sections 4.6, 4.7, Chapter 5, Section 5.1,)
UNIT 5: $L^2(\mathbb{R})$ and approximate Identities, The Fourier Transform on $\mathbb{R}$, Multiresolution Analysis and Wavelets, Construction of MRA (Chapter 5, Sections 5.2, 5.3, 5.4)

Text Book: Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer-Verlag New York, (1999).

References:

1. Charles K. Chui, *An Introduction to Wavelets*, Academic (1992).
2. Ingrid Daubechies, *Ten Lectures on Wavelets*, SIAM, (1992).
3. K.R Unni, *Wavelets, Frames and Wavelet Bases in L^P Lecture notes*, Bhopal (1997).
4. Stephane Mallat, *A Wavelet Tour Of Signal Processing*, Academic Press (1999).
5. Don Hong, Jianzhong Wang, Robert Gardner, *Real Analysis with an Introduction to Wavelets*, Elsevier Academic Press (2005).
6. Yves Meyer, *Wavelets and Operators*, Cambridge University Press (1992).
7. John. J Beneditto, Michael W. Frazier *Wavelets-Mathematics and Applications*, CRC, (1994).
8. Eugenio Hernandez, Guido L. Weiss, *First course on wavelets*, CRC, (1996).

Semester IX or X
MAT 10919/ MAT 11019 : Advanced Optimization Methods and Machine Learning

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course provides a detailed theoretical background on optimization in machine learning with a knowledge on python implementation.

Outcome: After completing the course, students learn how to develop mathematical models in Machine learning and how the theory of Deep Learning is applied to develop algorithms for python implementation.

Text books:

1 Aggarwal, C. C., Aggarwal, L. F., & Lagerstrom-Fife. (2020). Linear algebra and optimization for machine learning (Vol. 156). Springer International Publishing.

Reference books:

1 Boyd, S., Boyd, S. P., & Vandenberghe, L. (2004). Convex optimization. Cambridge university press.

2 Noble, B., & Daniel, J. W. (1977). Applied linear algebra (Vol. 477). Englewood Cliffs, NJ: Prentice-Hall

3 Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. MIT press

4 Strang, G. (2019). Linear algebra and learning from data (Vol. 4). Cambridge: Wellesley-Cambridge Press.

5 Strang, G. (2016). Introduction to Linear Algebra (5th Edition). Wellesley Publishers (India), ISBN : 978-09802327-7-6.

Syllabus

Module 1: The Basics of Optimization, Convex Objective Functions, Properties of Optimization in Machine Learning, Computing Derivatives with respect to Vectors, Stochastic Gradient Descent, Use of Bias
(Sections 4.2, 4.3, 4.5, 4.6, 4.7.2, 4.7.3 of Text 1).

Module 2: Challenges in Gradient Based Optimization, Momentum Based Learning, AdaGrad, Newton Method, Newton Method for Linear Regression, Newton Method- Challenges and Solution
(Sections 5.2, 5.3.1, 5.3.2, 5.4, 5.5.1,5.6 of Text 1).

Module 3: Singular Value Decomposition- Introduction, SVD- A linear Algebra Perspective, SVD- An Optimization Perspective
(Sections 7.1 - 7.3 of Text 1)

Module 4: Applications of SVD- Dimensionality Reduction, Noise Removal, Moore- Penrose Pseudoinverse, Feature preprocessing, Outlier Detection, Feature Engineering, Numerical Algorithms for SVD, Python Implementation of SVD.
(Sections 7.4 - 7.5 of Text 1).

Module 5: Basics of Computational Graphs, Neural Networks as Directed Computational Graphs, Back-propagation in Neural Networks, Python Implementation of Feed Forward Back-Propagation Neural Network.
(Sections 11.1 - 11.2, 11.4 of Text 1).

Semester IX or X
MAT 10920/ MAT 11020 : Commutative Algebra

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course is an advanced course in algebra. This course discusses the theory of commutative rings. These rings are of fundamental significance in Mathematics because of its applications to other topics such as algebraic number theory, algebraic geometry and many other advanced topics in mathematics.
Learning Outcomes: After the completion of this course, the student should be able to

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 under ring homomorphisms; prime avoidance.
UNIT 2: Free modules; Projective Modules; Tensor Product of Modules and Algebras; Flat, Faithfully Flat and Finitely Presented Modules; Shanuels Lemma.
UNIT 3: Localisation and local rings, universal property of localisation, extended and contracted ideals and prime ideals under localisation, localisation and quotients, exactness property.
UNIT 4: Nagata's criterion for UFD and applications; equivalence of PID and one-dimensional UFD. Associated Primes and Primary Decomposition.
UNIT 5: Integral dependence, Going-up theorem, Integral Extensions: integral closure, Going-down theorem, Valuation rings, Chain Conditions. Definition and examples of Noetherian rings and Artinian rings.

Text Book: M.F. Atiyah and I.G. Macdonald, Introduction to commutative algebra, Addison-Wesley (1969).

References:

1. R.Y. Sharp: Steps in commutative algebra, LMS Student Texts (19), Cambridge Univ. Press (1995).
2. D. Eisenbud: Commutative algebra with a view toward algebraic geometry GTM (150), Springer-Verlag (1995).
3. H. Matsumura: Commutative ring theory, Cambridge Studies in Advanced Mathematics No. 8, Cambridge University Press (1980).
4. N.S. Gopalakrishnan: Commutative Algebra (Second Edition), Universities Press (2016).
5. Miles Reid: Undergraduate Commutative Algebra , Cambridge University Press (1995).

Semester IX or X
MAT 10921/ MAT 11021 : Graph Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: The course introduce the concept of automorphism of simple graphs, graph operators, graph parameters and some interesting graph classes
Learning Outcomes: After the completion of this course, the student should be able to

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, Cayleys Formula, Applications (Chapter 3:Sec.3.1 3.4 (Theorem 3.4.3 omitted), Chapter 4: Sec. 4.1 - 4.5, 4.7)
UNIT 3: Independent sets, Vertex coverings, Edge Independent sets, Matchings, Factors, Matching in Bipartile Graphs, Eulerian Graphs, Hamiltonian Graphs, Hamilton Cycles in Line Graphs, 2-Factorable Graphs (Chapter 5: Sec. 5.1 - 5.5, Chapter 6: Sec. 6.1 - 6.3, 6.5 - 6.6)
UNIT 4: Graph Colorings, Critical Graphs, Brooks 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, Eulers Formula, Dual, Four Color Theorem and Five Color Theorem, Kuratowskis Theorem (without proof), Hamilton Plane graphs, Domination, Bounds, Independent Domination and Irredundance (Chapter8: Sec. 8.1 8.8, Chapter 10: Sec.10.1 10.3. 10.5)
Text Book: R. Balakrishnan, K. Ranganathan: A Text book of Graph Theory (Second Edition), Springer 2012.
References:-

1. D. B. West: Introduction to Graph Theory, 2nd ed. Prentice Hall, New Jersey (2011)
2. F. Harary: Graph Theory, Addison Wesley Publishing Company, Inc. (1969).
3. M. C. Golumbic: Algorithmic Graph Theory and Perfect Graphs, Academic Press, New York (1980)
4. Teresa W. Haynes, S. T. Hedetneimi, P. J. Slater: Fundamentals of Domination in Graphs, Marcel Dekker, New York (1998)

Semester IX or X

MAT 10922/ MAT 11022 : C^*-Algebra and Representation Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course aims to provide the fundamentals of C^*-algebras, Von Neumann algebras and their representation theory.
Outcome: After this course student can able to read and understand recent research articles in the representation theory of C^*-algebras. Student can able to work on some problem in representation theory of C^*-algebras.
Text book:

1. Murphy, Gerard J. C^*-algebras and operator theory. Academic Press, Inc., Boston, MA, 1990.

Reference books:

1. Arveson, William. An invitation to C^*-algebras. Graduate Texts in Mathematics, No. 39. Springer-Verlag, New York-Heidelberg, 1976.

2. Sunder, V. S. Functional analysis. Spectral theory. Birkhuser Advanced Texts: Basler Lehrbcher. [Birkhuser Advanced Texts: Basel Textbooks] Birkhuser Verlag, Basel, 1997.

3. Conway, John B. A course in functional analysis. Second edition. Graduate Texts in Mathematics, 96. Springer-Verlag, New York, 1990.

4. Davidson, Kenneth R. C^*-algebras by example. Fields Institute Monographs, 6. American Mathematical Society, Providence, RI, 1996.

5. Douglas, Ronald G. Banach algebra techniques in operator theory. Second edition. Graduate Texts in Mathematics, 179. Springer-Verlag, New York, 1998.

SYLLABUS

Module 1: C^*-Algebras and Hilbert Space Operators: C^*-Algebras, Positive Elements of C^*-Algebras, Operators and Sesquilinear Forms, Compact Hilbert Space Operators and The Spectral Theorem. (Chapter - 2 of Text Book - 1).
Module 2: Ideals and Positive Functionals: Ideals in C^*-Algebras, Hereditary C^*-Subalgebras , Positive Linear Functionals, The Gelfand-Naimark Representation and Toeplitz Operators. (Chapter - 3 of Text Book - 1).
Module 3: Von Neumann Algebras: The Double Commutant Theorem, The Weak and Ultraweak Topologies, The Kaplansky Density Theorem and Abelian Von Neumann Algebras. (Chapter - 4 of Text Book - 1).
Module 4: Representations of C^*-Algebras: Irreducible Representations and Pure States, The Transitivity Theorem, Left Ideals of C^*-Algebras, Primitive Ideals, Extensions and Restrictions of Representations, Liminal and Postliminal C^*-Algebras. (Chapter - 5 of Text Book - 1).
Module 5: Direct Limits and Tensor Products: Direct Limits of C^*-Algebras, Uniformly Hyperfinite Algebras, Tensor Products of C^*-Algebras, Minimality of the Spatial C^*-Norm and Nuclear C^*-Algebras and Short Exact Sequences. (Chapter - 6 of Text Book - 1).

Semester IX or X
MAT 10923/ MAT 11023 : Reproducing Kernel Hilbert Spaces

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours
Objective: Reproducing kernel Hilbert spaces have developed into an important tool in many areas, especially statistics and machine learning, and they play a valuable role in complex analysis, probability, group representation theory, and the theory of integral operators. This course aims to provide an introduction to the theory of reproducing kernel Hilbert spaces.
Outcome: After this course student can able to read and understand recent research articles in the theory of reproducing kernel Hilbert spaces. Student can able to work on some problem in reproducing kernel Hilbert spaces.
Text book:

1. Paulsen, Vern I.; Raghupathi, Mrinal. An introduction to the theory of reproducing kernel Hilbert spaces. Cambridge Studies in Advanced Mathematics, 152. Cambridge University Press, Cambridge, 2016.

Reference books:

1. Jim Agler and John E. McCarthy, Pick interpolation and Hilbert function spaces, Graduate Studies in Mathematics, vol. 44, American Mathematical Society, Providence, Rhode Island, 2002.
2. N. Aronszajn, Theory of reproducing kernels, Trans. Amer. Math. Soc. 68 (1950), 337404.
3. Ronald G. Douglas and Vern I. Paulsen, Hilbert modules over function algebras, Pitman Research Notes in Mathematics, vol. 217, Longman Scientific, 1989.
4. John B. Conway, A course in functional analysis, 2nd ed., Graduate Texts in Mathematics, vol. 96, Springer-Verlag, New York, 1990.
5. Donald Sarason, Complex function theory, American Mathematical Society, Providence, Rhode Island, 2007.

SYLLABUS

Module 1: Introduction: Definition of reproducing kernel Hilbert spaces (RKHS), Basic examples, Examples from analysis, Function theoretic examples. (Chapter - 1 of Text Book - 1).
Module 2: Fundamental results: Hilbert space structure, Characterization of reproducing kernels, The Reconstruction Problem. (Chapter - 2 of Text Book - 1).
Module 3: Interpolation and approximation: Interpolation in an RKHS, Strictly positive kernels, Best least squares approximants, The elements of H(K). (Chapter - 3 of Text Book - 1).
Module 4: Cholesky and Schur: Cholesky factorization, Schur products and the Schur decomposition, Tensor products of Hilbert spaces, Kernels arising from polynomials and power series. (Chapter - 4 of Text Book - 1).
Module 5: Operations on kernels: Complexification, Differences and sums, Finite-dimensional RKHSs, Pull-backs, restrictions and composition operators Composition operators, Products of kernels and tensor products of spaces, Push-outs of RKHS, Multipliers of a RKHS. (Chapter - 5 of Text Book - 1).

Semester IX or X
MAT 10924 / MAT 11024 - Topology II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: With this course, the students will have a sound introductory knowledge of the topics in Algebraic topology. The first module is important to understand the topology of non-metric spaces. From second module onwards the student is gradually introduced to the important category of topological spaces and subsequently the algebraic machinery like simplicity homology and fundamental groups for their study. The course ends with a rigorous understanding of covering spaces.
Learning Outcomes: After completion of this course, the students 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 (Tychnoffs 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 Poincares Theorem, Pseudomanifolds and the homology groups of S_n. **Simplicial Approximation:** Introduction, Simplicial approximation, Induced homomorphisms on the Homology groups, The Brouwer fixed point theorem and related results (Sections 2.4, 2.5, and Sections 3.1 to 3.4 from text 2)
UNIT 4: The Fundamental Group: Introduction, Homotopic Paths and the Fundamental Group, The Covering Homotopy Property for S1, Examples of Fundamental Groups. (Sections 4.1 to 4.4 from text 2)
UNIT 5: Covering Spaces: The Definition and Some Examples, Basic Properties of Covering Spaces, Classification of Covering Spaces, Universal Covering Spaces, Applications (Sections 5.1 to 5.5 of text 2)
Text Books:

1. K.D. Joshi: Introduction to General Topology (Revised Edn.),New Age International(P) Ltd., New Delhi, 1983.
2. F.H. Croom: Basic Concepts of Algebraic Topology, Springer, 1978

References:-

1. Allen Hatcher: Algebraic Topology, Cambridge University Press, 2002
2. C.T.C. Wall: A Geometric Introduction to Topology, Addison-Wesley Pub. Co. Reading Mass, 1972
3. Eilenberg S, Steenrod N.: Foundations of Algebraic Topology, Princeton Univ. Press, 1952.
4. J. R. Munkers: Elements Of Algebraic Topology, Perseus Books, Reading Mass, 1993, CRC, 2018.
5. J. R. Munkers: Topology (Second Edition) PHI, 2009.
6. Massey W.S.: Algebraic Topology : An Introduction, Springer Verlag NY, 1977
7. S.T. Hu: Homology Theory, Holden-Day, 1965

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 Physical and Mathematical Sciences
on 24th July 2023

(From 2023 admission onwards)

Cochin University of Science and Technology
Cochin - 682 022

Website: http://physics.cusat.ac.in

Scheme and Syllabus

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 quality advanced training in Physics to students through its 5 year Integrated M.Sc. program and carrying out excellent 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 various computational tools in the curriculum helps students progress in tune with the times.

Program Outcomes: Integrated M.Sc.

- Demonstrate a comprehensive understanding of fundamental principles and concepts in basic sciences, including mathematics, physics, chemistry, biology, and statistics.
- Analyze, evaluate, and synthesize complex scientific information and data using appropriate methods and techniques.
- Apply scientific reasoning and critical thinking to identify and solve problems in basic sciences.
- Communicate scientific information effectively and demonstrate proficiency in the use of modern scientific tools and technologies for experimentation, data collection, analysis, and interpretation.
- Apply ethical principles and practices in the conduct of scientific research and professional activities and work collaboratively with others.
- Engage in lifelong learning and professional development to enhance the knowledge and skills in basic sciences.

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 lifelong learning.
- Acquire firsthand experience in scientific research by working on research problems at the forefront.
- Acquire excellent abilities in various aspects of science communication.

Table of Contents

Scheme

Semester – I

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
ENG 10101	English -I	AEC	2-0-0	50	50	100	2
MAL 10101	Malayalam - I*	AEC	2-0-0	50	50	100	2
HIN 10101	Hindi - I*	AEC	2-0-0	50	50	100	2
GER 10101	German - I*	AEC	2-0-0	50	50	100	2
PHY 10101	General Physics - I	DSC	3-1-0	50	50	100	3
PHY 10102	Physics Lab - I (Mechanics)	DSC	0-0-4	100	–	100	2
PHY 10103	Topics in Quantitative Techniques - I	DSE	2-1-0	50	50	100	2
CHE 10101	General Chemistry - I	DSC	3-1-0	50	50	100	3
CHE 10102	Quantitative Analysis Lab	DSC	0-0-4	100	–	100	2
MAT 10101	Calculus - I	DSC	3-1-0	50	50	100	3
MAT 10103	Mathematical Methods - I	MDC	3-1-0	50	50	100	3
BIO 10103	General Biology	MDC	3-1-0	50	50	100	3
STA 10101	Statistical Methods for Data	MDC	3-1-0	50	50	100	3
CSP 10101	Computer Science - I	MDC	3-1-0	50	50	100	3
Semester Credits	22 (AEC: 4, DSC: 13, DSE: 2, MDC: 3) Cumulative Credits: 22						

*Either Malayalam - I, Hindi - I or German - I is to be opted.
Only one MDC to be opted.
AEC - Ability Enhancement Course, DSC- Discipline Specific Core, DSE - Discipline Specific Elective, MDC - Multidisciplinary Course
L- Lecture, T - Tutorial, P - Practical

Semester – II

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
ENG 10201	English -II	AEC	2-0-0	50	50	100	2
MAL 10201	Malayalam - II*	AEC	2-0-0	50	50	100	2
HIN 10201	Hindi - II*	AEC	2-0-0	50	50	100	2
GER 10201	German - II*	AEC	2-0-0	50	50	100	2
PHY 10201	General Physics - II	DSC	3-1-0	50	50	100	3
PHY 10202	Physics Lab - II (Waves and Optics)	DSC	0-0-4	100	–	100	2
PHY 10203	Electrostatics and Magnetostatics	DSE	2-1-0	50	50	100	2
CHE 10201	General Chemistry - II	DSC	3-1-0	50	50	100	3
CHE 10202	Inorganic Qualitative Analysis Lab	DSC	0-0-4	100	–	100	2
MAT 10201	Calculus - II	DSC	3-1-0	50	50	100	3
MAT 10203	Mathematical Methods - II	MDC	3-1-0	50	50	100	3
BIO 10203	Biophysical Chemistry	MDC	3-1-0	50	50	100	3
STA 10201	Probability and Distributions	MDC	3-1-0	50	50	100	3
CSP 10201	Computer Science - II	MDC	3-1-0	50	50	100	3
Semester Credits	22 (AEC: 4, DSC: 13, DSE: 2, MDC: 3) Cumulative Credits: 44						

*Either Malayalam - II or Hindi - II or German - II is to be opted.
Only one MDC to be opted.

Semester – III

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
PHY 10301	General Physics - III	DSC	3-1-0	50	50	100	3
PHY 10302	Physics Lab - III (Electricity and Magnetism)	DSC	0-0-4	100	–	100	2
PHY 10303	Topics in Quantitative Techniques - II	DSE	2-1-0	50	50	100	2
CHE 10301	General Chemistry - III	DSC	3-1-0	50	50	100	3
CHE 10302	Organic Qualitative Analysis Lab	DSC	0-0-4	100	–	100	2
VAC 10301	Environmental Science and Sustainability	VAC	4-1-0	50	50	100	4
MAT 10301	Calculus - III	DSC	3-1-0	50	50	100	3
MAT 10303	Matrix Theory and Graph Theory	MDC	3-1-0	50	50	100	3
BIO 10303	Human Disease and Healthcare management	MDC	3-1-0	50	50	100	3
STA 10301	Statistical Inference	MDC	3-1-0	50	50	100	3
CSP 10301	Computer Science - III	MDC	3-1-0	50	50	100	3
Semester Credits	22 (DSC: 13, DSE: 2, MDC: 3, VAC: 4) Cumulative Credits: 66						

VAC - Value Added Course
Only one MDC to be opted.

Semester – IV

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
PHY 10401	Classical mechanics and Relativity	DSC	4-1-0	50	50	100	4
PHY 10402	Electricity and Magnetism	DSC	4-1-0	50	50	100	4
PHY 10403	Basic Mathematical Physics	DSC	4-1-0	50	50	100	4
PHY 10404	Basic Electronics	DSC	4-1-0	50	50	100	4
PHY 10405	Physics Lab - IV (Electronics)	DSC	0-0-8	100	–	100	4
SEC 104xx	Skill Enhancement Course - I	SEC	3-1-0	100	–	100	3
Semester Credits	23 (DSC: 20, SEC: 3) Cumulative Credits: 89						

SEC - Skill Enhancement Course

Semester – V

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
PHY 10501	Thermal Physics	DSC	4-1-0	50	50	100	4
PHY 10502	Introduction to quantum mechanics	DSC	4-1-0	50	50	100	4
PHY 10503	Optics and spectroscopy	DSC	4-1-0	50	50	100	4
PHY 10504	Numerical and Computational Physics	DSC	4-1-0	50	50	100	4
PHY 10505	Physics Lab - V (Computer Lab)	DSC	0-0-8	100	–	100	4
SEC 105xx	Skill Enhancement Course - II	SEC	3-1-0	100	–	100	3
Semester Credits	23 (DSC: 20, SEC: 3) Cumulative Credits: 112						

Semester – VI

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
PHY 10601	Basic Solid State Physics	DSC	4-1-0	50	50	100	4
PHY 10602	Basic Nuclear physics and Applications	DSC	4-1-0	50	50	100	4
PHY 106xx^*	Elective	DSE	4-1-0	50	50	100	4
PHY 106xx^*	Elective	DSE	4-1-0	50	50	100	4
PHY 10605	Physics Lab - VI (Modern Physics)	DSC	0-0-8	100	–	100	4
SEC 106x	Skill Enhancement Course - III	SEC	3-1-0	100	–	100	3
Semester Credits	23 (DSC: 20, SEC: 3) Cumulative Credits: 135						

BSc Exit with 135 Credits Or Merge with MSc

Credit Breakup: Physics – 82 ($\sim$ 61%), Chemistry – $>$ 15 ($\sim$ 11%), Mathematics – $>$ 9 ($>$ 7%), SEC – 9 ($\sim$ 7%), AEC-8 ($\sim$ 6%), MDC – 9 ($\sim$ 7%), VAC – 4 ($\sim$ 3%)

Semester – VII

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
PHY 10701	Mathematical Physics	DSC	4-1-0	50	50	100	4
PHY 10702	Classical Mechanics	DSC	4-1-0	50	50	100	4
PHY 10703	Electrodynamics	DSC	4-1-0	50	50	100	4
PHY 10704	Quantum Mechanics	DSC	4-1-0	50	50	100	4
PHY 10705	Advanced Experiments in Physics Lab-I	DSC	0-0-9	100	–	100	4
Semester Credits	20 (DSC: 20) Cumulative Credits: 155						

Semester –VIII: Honours Stream

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
PHY 10801	Statistical Mechanics	DSC	4-1-0	50	50	100	4
PHY 10802	Atomic and Molecular Spectroscopy	DSC	4-1-0	50	50	100	4
PHY 108xx^*	Elective	DSE	4-1-0	50	50	100	4
PHY 108xx^*	Elective	DSE	4-1-0	50	50	100	4
PHY 10805	Advanced Experiments in Physics Lab-II	DSC	0-0-9	100	–	100	4
VAC 10806	Student Seminar	VAC	2-0-0	100	–	100	2
Semester Credits	22 (DSC: 12, DSE: 8, VAC:2) Cumulative Credits: 177						

Exit with BSc Honours (177 Credits)

Semester –VIII: Honours with Research Stream

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
PHY 10801	Statistical Mechanics	DSC	4-1-0	50	50	100	4
PHY 10802	Atomic and Molecular Spectroscopy	DSC	4-1-0	50	50	100	4
PHY 10803	Project	DSC	0-4-0	100	100	200	12
VAC 10806	Student Seminar	VAC	2-0-0	100	–	100	2
Semester Credits	22 (DSC: 8, VAC: 2, Project: 12) Cumulative Credits: 177						

Exit with BSc Honours with Research (177 Credits)

Semester – IX

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
PHY 10901	Nuclear and Particle Physics	DSC	4-1-0	50	50	100	4
PHY 10902	Advanced Solid State Physics	DSC	4-1-0	50	50	100	4
PHY 109xx^*	Elective	DSE	4-1-0	50	50	100	4
PHY 109xx^*	Elective	DSE	4-1-0	50	50	100	4
PHY 10905	Advanced Experiments in Physics Lab-III	DSC	0-0-9	100	–	100	4
Semester Credits	20 (DSC: , Elective: 8) Cumulative Credits: 197						

Semester – X

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
PHY 11001	Major Project@	DSC	0-5-0	100	100	200	16
PHY 110xx	Online course **	MDC	2-1-0	–	100	100	2
Semester Credits	18 (DSC: 16, MDC: 2) Cumulative Credits: 215						

Total credit requirement for BSc: 133

Total credit requirement for BSc Honours: 177

Total credit requirement for BSc Honours with Research: 177

Total credit requirement for Integrated MSc: 215

* Replace xx with selected elective course codes.
@**Regarding the Major Project the following directions will appply:**

(a) The major project can be done within the department or in an external institution of National/International reputation. i.e. institutions like, IISc Bangalore, Various IIT's, IISERs, Central Universities, CSIR laboratories, NITs TIFR, Raman Research Institute, IIA, inter university centers like IUCAA, NPOL, ISRO, DRDO, IIEST, industrial organizations, etc and any other equivalent institution.

(b) If a student wants to do his/her project in an external institution he/she has to find the supervisor from a nationally/internationally reputed institution like as mentioned above. A consent letter from the external supervisor should be produced to the Department Head/Coordinator of the batch. The consent letter can be considered by the Department council/Department Head and approval can be given to the student to pursue the project with the supervisor concerned.

(c) An internal faculty in charge must be assigned by the Department Council/Department Head to each student who is doing the project in other institutions/departments.

(d) The internal faculty in charge will periodically monitor the progress of the students assigned to him/her.

(e) Continuous evaluation of the project must be done by the supervisor. In the case of projects done outside the department, this can be done either by the external supervisor alone or by internal faculty in charge (in cases where the external supervisor is not able produce an official evaluation statement) or by both the internal and external supervisors together.

(f) The department shall arrange mid-term presentations for all students. These will form a part of the continuous evaluation.

(g) The students must submit a report at the end of the project, which is duly signed and recommended by the supervisor on or before the date stipulated by the Department. For projects done outside, the report must be duly signed by the external supervisor.

(h) The end semester evaluation in the form of a presentation followed by viva based on the project will be done in the Department by a committee appointed by the Department Council/Department Head.

** Online course PHY 110*xx* 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 length of a course, the relevance of its content to the program, etc. 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 semester but before the submission of the final project report.

(d) At the end of the course, the student should produce a valid document regarding the successful completion of the Course and stating his/her marks/grades. The Department Council will ascertain that the document produced is satisfactory and recommend awarding two (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 informing the council.

Syllabus

Semester I

PHY 10101: General Physics - I

Credits: 3
Hours : 45 hours

Course Objective

This paper intends to develop the understanding of physics and its methods to enable students to analyze systems using basic rules of mechanics.

Course Outcome

:

1. Understand the notion of units and dimensions of physical quantities.
2. Understand Newton's laws of motion and apply the laws in order to analyze basic dynamics of physical systems.
3. Acquire the capacity to use the energy conservation principle to understand the dynamics of a system.
4. Familiarize the rules of understanding the different properties of the material world, like elasticity, surface tension, etc.

Module I General introduction: Measurements and Units, Vectors: Notation, addition and multiplication of vectors, scalar and vector products, velocity and acceleration, Laws of motion: Equations of motion, Applications of Newton's laws of motion, motion under gravitational force, law of universal gravitation, motion under electric and magnetic forces, momentum conservation, friction.

Module II Conservation laws: Conservation of energy, conservative forces, power, Conservation of linear and angular momentum, recoil of a gun, center of mass frame, systems with variable mass. Harmonic oscillator: Example systems, kinetic and potential energy, forced oscillations.

Module III Rigid-body dynamics: Equation of motion, angular momentum and kinetic energy, moments of inertia, rotations about fixed axes, parallel axis theorem, perpendicular axis theorem, 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, 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 (Poiseuille's formula)- Stokes formula, Surface tension, surface energy.

Text Books:

1. Mechanics, C. Kittel, W.D. Knight, M.A. Ruderman, C.A. Helmholz and B.J. Moyer, Berkeley Physics Course Vol 1, Tata McGraw-Hill Ltd (2008). (Chapters 1-9).
2. Elements of Properties of Matter, D. S. Mathur, S. Chand & Co (2008).

Reference Books:

1. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chap- ters 1-14).
2. Mechanics, L.D. Landau and I.M. Lifshitz, 3rd edition, Elseviar (2007).
3. The Feynman Lectures on Physics Vol I, Narosa Publications (2003). (Chapters 1-25).

PHY 10103: Topics in Quantitative Techniques - I

Credits: 2
Hours : 30 Hours

Course Objective

To gain basic understanding on some of the mathematical tools required for analysis of physical systems.

Course Outcome

:

1. To understand and analyze systems using different coordinate systems.
2. To familiarize with curvilinear coordinates and their derivatives at an introductory level.
3. To have an understanding on the principle of superposition and its consequences.
4. To work out the basic approximation methods that are essential at the undergraduate level.
5. To use linear algebra effectively to analyse problems.

Module I Curvilinear coordinates- Spherical coordinates, cylindrical coordinates. Vectors in polar coordinates. Motion in plane polar coordinates, (Kleppner and R.J. Kolenkow, Chapter 1,2) Introduction to linear systems and concepts of superposition, Introductions to Approximate methods, taylor series, series representation of functions, differentials, basic characteristics of important functions such as exponential, logarithmic, sinc, Polynomials and their combinations, ideas on polar plot (Feynman Lectures Ch.25, Kleppner, R.J. Kolenkow, Chapter 1, Pgs.36-39)

Module II 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, diagonalization, simultaneous linear equations.

Text Books:

1. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).
2. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973
3. Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education

Reference Books:

1. Basic Training in Mathematics: A Fitness Program for Science Students By R. Shankar, Springer; 1995th edition.
2. Mathematical Methods for Physicists Paperback (7th Edition), Arfken, Elsevier (2012).

Semester II

PHY 10201: General Physics - II

Credits: 3
Hours : 45 hours

Course Objective

The course is designed to develop the idea of light as an electromagnetic wave, introduces the properties of light and sound waves.

Course Outcome

:

1. Enable the students to calculate electric field and electric potential due to various charge distributions.
2. Introduces the magnetic effect of electric current and the concept of electromagnetic waves.
3. Explores the properties of electromagnetic waves and the consequence of wave nature of light.
4. Gave an understanding of mechanical waves and its properties.

Module I Electrostatics: Electric field, Electric field of – a ring of charge, charged line segment, uniformly charged disk, two oppositely charged infinite sheets. Gauss's law – Calculation of electric field using Gauss's law- charged sphere (conducting and insulating), oppositely charged parallel conducting plates. Electric potential, calculation of electric potential of – charged conducting sphere, oppositely charged parallel plates, infinite line/charged conducting cylinder, ring of charge, line of charge. Chapters 21-23 University Physics, H.D. Young, Roger A Freedman

Module II Magnetic effect of electric current and EM waves: Magnetic field, magnetic field lines and magnetic flux, motion of charged particles in a magnetic field, applications of motion of charged particles, Magnetic force on current carrying conductor, Hall effect, Ampere's law and application, Faraday's law, Displacement current and Maxwell's equations. Chapters 27-32 University Physics, H.D. Young, Roger A Freedman

Module III Optics: Maxwell's equation and electromagnetic waves, plane electromagnetic waves and the speed of light, the nature of light, interference and coherent sources, intensity in interference patterns, interference in thin films, Fresnel and Fraunhofer diffraction, intensity in single slit diffraction, multiple slits, the diffraction grating, circular aperture and resolving power. Chapters 33, 35, 36 University Physics, H.D. Young, Roger A Freedman

Module IV Sound: Mathematical description of a wave, speed of a transverse wave, Energy in wave motion, Sound waves, speed of sound waves, sound intensity and loudness, standing waves and normal modes, resonance and interference of sound waves, Shock waves, quality of sound, musical instruments, Fourier analysis, from analog to digital. Chapter 15-16, University Physics, H.D. Young, Roger A Freedman, Chapters 21, Conceptual Physics - Paul G Hewitt

Text Books:

1. University Physics, H.D. Young, Roger A Freedman
2. Conceptual Physics - Paul G Hewitt.

Reference Books:

1. Waves, F.S. Crawford Jr, Berkeley Physics Course Volume 3, Tata McGraw-Hill Ltd (2008)
2. Cohen B. L., Concepts of Nuclear Physics, Tata McGraw Hill (2008). Introduction to Electrodynamics, D. J. Griffiths, 4th Edition, Cambridge University Press (2017).
3. Electricity and Magnetism, Purcell, Berkeley Physics Course Volume 2, Tata McGraw-Hill Ltd (2008)
4. The Feynman lectures Volume I and Volume II, Narosa (2003)

PHY 10203: Electrostatics and Magnetostatics

Credits: 2
Hours : 30 hours

Course Objective

To provide an understanding on the fundamentals of electrostatics and magnetostatics.

Course Outcome:

1. Enable the students to have an understanding on the boundary value problems of electrostatics.
2. The concept of vector potential and its boundary conditions will be understood.

Module I The electric field, the electric potential, Laplace equation in one dimension, two dimension and three-dimension, Boundary conditions and uniqueness theorems, The method of images- the classic image problem, induced surface charge, force, and energy.
Chapter 2 and Chapter 3: Introduction to Electrodynamics, David. J. Griffiths

Module II The Lorentz force law, Biot -Savart law, The divergence and curl of B, Vector potential, Magnetostatic boundary conditions.
Chapter 5, Introduction to Electrodynamics by David J Griffiths.

Text Books:

1. Introduction to Electrodynamics, D. J. Griffiths, 4th Edition, Cambridge University Press (2017).

Reference Books:

1. Electricity and Magnetism, Purcell, Berkeley Physics Course Volume 2, Tata McGraw-Hill Ltd (2008)
2. The Feynman lectures Volume II, Narosa (2003)

Semester III

PHY 10301: General Physics - III

Credits: 3
Hours : 45 hours

Course Objective

This course provides an introduction to the theoretical foundations of modern physics developed in the early 20th century. This includes the theory of relativity, quantum theory, and nuclear physics.

Course Outcome

:

1. Understand relativity as an extension of Newtonian mechanics and its consequences.
2. Understand the emergence of photon picture of light and wave-particle duality.
3. Understand the significance of the wave picture of electrons and its crucial role in atomic models.
4. Learn fundamental nuclear properties, models, phenomena, and applications.

Module I Special Relativity; Frames of reference; postulates of special relativity - Michaelson-Morely experiment; Relativity of Simultaneity - Time dilation; Doppler Effect; Length Contraction; Mass Energy equivalence and relativistic energy - Kinetic Energy at low speeds - massless particles.

Module II Continuous spectra: Black body radiation - Rayleigh and the Ultraviolet Catastrophe - Planck and Quantum Hypothesis. Light waves behaving as particles: Light absorbed as photons: The photoelectric effect - Stopping Potential - Einstein's explanation - Photon momentum; Light emitted as photons: X-ray production; Light scattered as photons - Compton scattering; Wave-particle duality - diffraction and interference in photon picture; The uncertainty principle - Probability and uncertainty - waves and uncertainty - Uncertainty in energy.

Module III Particles behaving as waves: Electron waves - observing wave nature of electrons - de-Broglie waves - The electron microscope; The atom and atomic spectra: line spectra - The Rutherford experiment - failure of classical physics; Energy Levels and the Bohr Model of atom - photon emission and absorption - The Frank Hertz experiment - Electron waves and the Bohr model- Hydrogen levels in Bohr model - The uncertainty principle - Heisenberg uncertainty principle for matter - Limits of Bohr Model;

Module IV Discovery of the nucleus - Nomenclature and classification of nuclides - Properties of the nucleus - Nuclear radius and density - Nuclear mass and binding energy - Separation energy of last nucleon - Nuclear Forces - Nuclear Stability - Radioactive decay law - Alpha, Beta, and Gamma radiations - Radiation applications - Nuclear Fission and Fusion - Nuclear reactors.

Text Books:

1. University Physics- H D Young & R A Freedman, 13th edition, Pearson Edition, 2006 (Modules 2,3,4; Chapter 38,39,43).
2. Concepts of Modern Physics - Arthur Beiser, 6th edition, 2017 (Module 1; Chapter 1).

Reference Books:

1. Quantum Physics- Berkeley Physics Course, Vol IV, Tata McGraw Hill, 2008

PHY 10303: Topics in Quantitative Techniques - II

Credits: 2
Hours : 30 hours

Course Objective

To gain basic understanding on some of the mathematical tools required for analysis of physical systems.

Course Outcome

:

1. Use multivariable calculus to analyse various problems.
2. Use basic data analysis to analysis experimental data.

Module I Vector analysis: Vector algebra- vector operations, vector algebra-component form, triple products, position, displacement and separation vectors, transformation properties of vectors. Differential calculus – ordinary derivatives, gradient, the del operator, the divergence, the curl, product rules, second derivatives, Integral calculus- line, surface and volume integrals, the fundamental theorem of calculus, the fundamental theorem for gradients, the fundamental theorem for divergences, the fundamental theorem for curls, The Dirac delta function- one-dimensional Dirac delta function, the three-dimensional delta function- $\vec{\nabla} \cdot \left(\frac{\hat{(r)}}{r^2} \right)$ (D.J. Griffiths,Chapter 1)

Module II Analysing data from experiments: Systematic and random errors, quantifying error, Precision and accuracy, Error propagation, random variables, Probability distributions, Mean and Variance, Estimation of mean and variance from data, Central Limit Theorem, Basics of visualization of experimental data. Testing statistical models

Text Books:

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., Pearson Education
2. The Statistical Analysis of Experimental Data, John Mandel, Dover Publications 1985.

Reference Books:

1. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).
2. The Art of Statistics: Learning from Data, David Spiegelhalter, Pelican Books 2020

Semester IV

PHY 10401: Classical Mechanics and Relativity

Credits: 4
Hours : 60 hours

Course Objective

This intends to develop the basics methods of analysing non-inertial frames, Rigid body dynamics, elements of fluid dynamics and special theory of relativity.

Course Outcome:

1. Understand the motion within a non-inertial frame.
2. Enable the students to apply the Newtons law in understanding the basics of rigid body dynamics
3. Acquire basic knowledge in fluid dynamics
4. Get a hands on the preliminaries of special theory of relativity.

Module I Concepts of Inertial frames, force and mass.Galilean transformations and Galilean invariance. Solution of the equations of motion (E.O.M.) in simple force fields in one, two and three dimensions using Cartesian, cylindrical polar and spherical polar coordinate systems. Non-inertial systems: - Idea of fictitious forces - Physics in a rotating coordinate system - Equation of motion with respect to a uniformly rotating frame - Centrifugal and Coriolis forces

Module II The Rigid Body: Constraints defining the rigid body. Degrees of freedom for a rigid body; (b) Relation between Angular momentum and Angular Velocity: Moment of Inertia Tensor. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies.

Module III Basics Lagrangian formulation: definition of Lagrangian with examples- Lagrangian of free particle, Lagrangian of harmonic oscillator, Lagrangian of freely falling particle. Concept of the principle of least action: definition of action, principle of least action, variation of action for a particle moving in a potential V (x) and derivation of Newton's law of motion.

Module IV Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Relativistic transformation of velocity. Mass-energy Equivalence.
Transformation of Energy and Momentum. Invariant interval, Space-time diagrams. Proper time and Proper velocity. Relativistic energy and momentum.

Text Books:

1. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw- Hill
2. Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
3. Fundamentals of Physics I, R. Shankar, Yale University Press, London (2019)
4. Introduction to Special Relativity, R. Resnick, 2010, John Wiley and Sons
5. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., Pearson Education

Reference Books:

1. Mechanics, C. Kittel, W.D. Knight, M.A. Ruderman, C.A. Helmholz and B.J. Moyer, Berkeley Physics Course Vol 1, Tata McGraw-Hill Ltd (2008). (Chapters 1-9)

2. Elements of Properties of Matter, D. S. Mathur, S. Chand & Co (2008).

PHY 10402: Electricity and Magnetism

Credits: 4
Hours : 60 hours

Course Objective

This course will help in understanding basic concepts of electricity and magnetism and their applications.

Course Outcome:

1. To familiarize the ideas of polarization and dielectric media
2. Students will understand the effect of magnetic field in linear and non-linear media
3. The Maxwell's equations and its significance will be explored
4. Conservation of charge and energy will be understood

Module I Electric field in matter: Polarization, the field of a polarized object, the electric displacement, linear dielectrics- Susceptibility, Permittivity, Dielectric constant.
Chapter 4, Introduction to Electrodynamics, David J Griffiths.

Module II Magnetic fields in matter: Magnetization, the field of a magnetised object, the auxiliary field H, Linear and nonlinear media.
Chapter 6, Introduction to Electrodynamics, David J Griffiths.

Module III Electrodynamics: Electromotive force, Electromagnetic induction, Maxwell's equations.
Chapter 7, Introduction to Electrodynamics, David J Griffiths.

Module IV Conservation laws: Charge and energy, The continuity equation, Poynting's theorem, Momentum.
Chapter 8 Introduction to Electrodynamics by David J Griffiths.

Text Books:

1. Introduction to Electrodynamics, D. J. Griffiths, Pearson Education India, 4th edition (2015).

Reference Books:

1. Electricity and Magnetism, Purcell, Berkeley Physics Course Volume 2, Tata McGraw-Hill Ltd (2008).
2. The Feynman lectures Volume II, Narosa (2003).

PHY 10403: Basic Mathematical Physics

Credits: 4
Hours : 60 hours

Course Objectives

This course introduces basic mathematical tools used in physics to the students. The course aims to prepare the students for understanding and applying various mathematical formalisms used in physics.

Course Outcomes

1. Solve basic problems in probability, understand Binomial and Poisson probability distributions and solve basic problems in sample statistics.

2. Acquire skill to solve first order and second order ordinary differential equation.

3. Demonstrate an understanding of Heaviside unit step function and Dirac delta function, an understanding of Fourier series and its applications, use integral transforms like Fourier and Laplace transform to solve ordinary differential equations with constant coefficients.

4. Acquire basic understanding of complex numbers and functions of complex variable.

Module I First order ordinary differential equations: General form of solution. First degree first order equations. Separable- variable equations, exact equations, inexact equations, integrating factors, linear equations, homogeneous equations, isobaric equations, Bernoulli's equation, miscellaneous equations. Solve second order differential equations with constant coefficients.

Module II Heaviside unit step and Dirac delta function. Fourier series, general properties, applications. Integral transforms: Fourier transforms, inversion theorem, Fourier transform of derivatives, convolution theorem. Elementary Laplace transforms, Laplace transform of derivatives, inverse Laplace transforms, solution of ordinary differential equations with constant coefficients.

Module III Complex numbers: Definition, arithmetic operations, conjugate, geometric interpretation. Powers and Roots: Polar form, DeMoivre's formula, Roots. Functions of a complex variable, limits and continuity, Derivative, Analytic functions, Entire functions. Cauchy Reimann Conditions for analyticity. Exponential and logarithmic functions, Trigonometric and hyperbolic functions.

Module IV Probability and statistics: Venn diagrams, probability, permutations and combinations, random variables and distributions, properties of distributions, important discrete distributions, Binomial, geometric and Poisson distributions. Experiments samples and populations, sample statistics, estimators and sampling distributions.

Text Books:

1. Tai L. Chow, Mathematical Methods for Physicists. A concise introduction, Cambridge University Press (2008).

2. George Arfken, Mathematical Methods for Physicists, Fourth (Prism Indian) 7th Edition, Elsevier (2012).

3. K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical methods for physics and engineering, Cambridge Universality Press (2006).

4. Advanced Engineering Mathematics, Dennis G Zill, Jones and Bartlett Publishers, 2018.

PHY 10404: Basic Electronics

Credits: 4
Hours : 60 hours

Course Objectives

This course aims to provide the fundamental understanding of analog and digital electronic components as well as the skills necessary to analyze and design basic electronic circuits.

Course Outcomes

1. Familiarise with circuit analysis, detailed understanding of diode characteristics and applications

2. Understanding the transistor characteristics and different types of amplifiers.

3. Understanding the basics of operational amplifiers.

4. Understanding basics of digital electronics.

Module I Ohms law, Kirchhoff's law- Ideal voltage and current sources- Thevenin's and Norton's theorem, Maximum power transfer theorem, Basic band theory of solids, Diode theory, forward and reverse-biased junctions, reverse-bias breakdown, load line analysis, diode applications - Limiters, clippers, Clampers, voltage multipliers, half wave and full wave rectification, Special purpose diodes - Zener diode, Varactor, light emitting diodes, Laser diodes.

Module II Transistor fundamentals, Review of the characteristics of transistor in CE and CB configurations, Regions of operation (active, cut off and saturation), transistor biasing, Current gains α and β. Relations between α and β, dc load line and Q point, AC analysis of BJT, Single and multi-stage-RC coupled transistor amplifiers, Concept of feedback, negative and positive feedback, Transistor oscillator circuits - phase shift, Hartley Oscillator, Colpitt oscillator, Field-Effect Transistors (FET).

Module III Ideal operational amplifier, practical Op Amp circuits, differential and Common mode operation, Inverting & Non-Inverting Amplifier, voltage follower, inverter, Op-Amp applications-Adder, Differentiator, and Integrator.

Module IV Number System – Introduction to binary, octal, decimal & hexadecimal systems, representation of negative numbers, 1's, 2's complement and their arithmetic, Boolean algebra – Boolean theorems, minimization of Boolean function, K-Map minimization. Basic logic gates, Boolean functions realization using logic gates, half & full adder, subtractor, Introduction to sequential logic, introduction to flip-flop, RS, D, T, JK flip-flops, race around condition, Master-slave JK flip-flops, flip-flop clocked sequential circuits.

Text Books:

1. Modern physics, Arthur Beiser, 6th Edition, Tata McGraw-Hill (2006). (Chapter-10).

2. A.S. Sedra & K.C.Smith, Microelectronics Circuits, Oxford University Press (1997).

3. Leach, Malvino, and Saha, Digital Principles and Applications, 5th Edition, McGraw Hill Education (1994).

4. A. Anand Kumar, Fundamentals of Digital Circuits (3rd Edition), PHI Learning Pvt. Ltd., New Delhi (2014).

Reference Books:

1. Robert L. Boylestad & Louis Nashelsky, Electronic Devices & Circuit Theory.
2. William Kleitz, Digital Electronics, Prentice Hall International Inc.
3. V. K. Metha, Rohit Metha, Principles of Electronics (S. Chand).
4. R. P. Jain, Thomas L. Floyd, Digital Fundamentals, Pearson Education (2005).

Semester V

PHY 10501: Thermal Physics

Credits: 4
Hours : 60 hours

Course Objectives

This course introduces basics of thermal physics to the students. The course aims to make the students understand and apply various concepts of thermodynamics.

Course Outcomes

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 path and collisions.

Module II Transport and thermal diffusion: Transport properties in gases, The thermal diffusion equation. The first law of thermodynamics: Energy, Isothermal and adiabatic processes.

Module III The second law of thermodynamics: Heat engines and the second law, entropy and the second law.

Module IV Thermodynamic potentials: Internal energy, Enthalpy, Helmholtz function, Gibbs function, Maxwell's relations. Third law of thermodynamics.

Text Book:

1. Concepts in thermal physics, S.J. Blundell and K. M. Blundell, Oxford University Press (2008). (Chapters 1-16, Chapter-18)

Reference Books:

1. Statistical Physics, F. Reif, Berkeley Physics Course, Volume 3, Tata- McGraw-Hill (2008).
2. Heat and Thermodynamics, M. Zemansky and R. Dittman, 7th Edition, McGraw-Hill (1997).
3. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters 17-20).

PHY 10502: Introduction to Quantum Mechanics

Credits: 4
Hours : 60 hours

Course Objective

The course aims to develop an understanding of the theoretical framework of Quantum Mechanics and its applications.

Course Outcome:

1. Introduction to Schrodinger's formulation of quantum mechanics.
2. Solve elementary problems in quantum mechanics to understand how they differ from classical mechanics.
3. Introducing HIlbert's space formulation for quantum mechanics.
4. Revisit the framework of quantum mechanics in Hilbert's space formalism.

Module I Review of wave properties of particles - De Broglie waves, Describing a wave, phase and group velocities, particle diffraction, uncertainty principle - applications, particle in a box. Quantum Mechanics - wavefunction - The wave equation - Schrodinger's equation: Time dependent form, Linearity and Superposition, Waves of probability, Normalization, Well-behaved wavefunctions; Expectation values, Operators - energy and momentum operators.

Module II Time independent Schrodinger Equation - Stationary states; The infinite square well; The Harmonic oscillator - analytic method; The free particle; The delta function potential; Tunnel Effect. Identical particles - The Two-particle system - Fermions and Bosons - exchange operator - symmetrization postulate.

Module III Mathematical Formalism: Linear vector spaces - inner product, Hilbert space, Wave Functions; Linear operators: Hermitian operators, Projection operators, Commutator algebra, Unitary operators, Eigenvalues and Eigenvectors of a Hermitian operator; Basis: Representation in discrete bases, Matrix representation of kets, bras, and operators, Change of bases and unitary transformations, Matrix representation of the eigenvalue problem, Representation in position bases.

Module IV Mathematical Formalism- Postulates of Quantum Mechanics: State - Probability Density - Superposition - Observables - Position and Momentum operators - Position and Momentum representation of state vector; Expectation values - Commuting operators and Uncertainty relations; Time dependent Schrodinger equation and its representation in position basis.
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.

Text Books:

1. Concepts of Modern Physics, Arthur Beiser, Tata McGraw-Hill, 7th Edition, (2015).
2. Introduction to Quantum Mechanics, D. Griffiths, 2nd Edition, Cambridge University (2017).
3. Nouredine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009 (Modules 3, 4).
4. Quantum Physics, H. C. Verma, Surya Publications, 2nd Edition (2009).
5. University Physics, H.D Young and R.A. Freedman, 12th Edition, Pearson (2009).

Reference Books:

PHY 10503: Optics and Spectroscopy

Credits: 4
Hours : 60 hours

Course Objective

This course aims to provide a comprehensive understanding of the principles and applications of optics and spectroscopy.

Course Outcome

:

1. Study and solve problems in wave propagation.
2. Use transverse nature of light to study optical phenomena and devices
3. Explain light amplification, basics of fibre optics, and nonlinear optical properties.
4. Assimilate concepts of spectroscopy and applications.

Module I Wave Optics Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Electromagnetic nature of light. Modulation, Superposition of two harmonic and travelling waves, Modulation velocity, Phase velocity and Group velocity, AM Radio waves, Electromagnetic radiation in vacuum, non-dispersive waves, waves in the ionosphere, surface waves in water. Pulses, Time-bandwidth product, solution to the pulse with square frequency spectrum.

Module II Polarization, Interference, and Diffraction Polarized light, polarization through dichroism, birefringence, scattering and reflection. Linear polarizers, wire-grid polarizer, polaroid, Nicol prism, retarders, full, half and quarter wave plates. Induced optical effects, Photoelasticity, Faraday effect, Cotton-Muton effect, Kerr effect and Pockels' effect. Optical modulators. Theory of interference of light, Michelson Interferometer, Lloyd's Mirror, Fresnel's Biprism. Multiple-beam interference, Fabry-Perot interferometer, applications to single and multilayer films, Fresnel diffraction, Fraunhofer diffraction: Single slit. Double slit. Multiple slits. Diffraction grating.

Module III Lasers, Nonlinear Optics, and Fibre Optics Absorption and emission, Stimulated emission, Population inversion, Einstein coefficients, Methods of Producing population inversion, Solid state lasers (Ruby, Nd:YAG), Gas lasers (He-Ne, CO_2), Q-switching, Mode-locking. Nonlinear optics (basics), Optical rectification, harmonic generation, Frequency mixing, two- photon absorption, self-focusing. Structure of an Optical Fibre, Liquid phase fibre fabrication, Ray propagation in step-index fibres, Ray propagation in graded-index fibres, Effect of material dispersion.

Module IV Basics of Spectroscopy Electromagnetic spectrum, Blackbody spectrum, Boltzmann population distribution, Einstein coefficients, Structure of atoms, Atomic quantum numbers, fine structure in Hydrogen atom, Normal and Anomalous Zeeman effect. Overview of molecular spectroscopy-classification of polyatomic molecules, Rotational spectra of rigid diatomic molecule, Applications of microwave spectroscopy, vibrational spectra of diatomic molecule, Introduction to Raman spectroscopy and instrumentation.

Text Books:

1. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, Tata McGraw-Hill (2007).
2. Optics (4 th Ed.) by E Hecht and A R Ganesan, Pearson (2019)
3. Introduction to Modern Optics, G R Fowles, Dover Publications (1975)
4. Optics, Ajoy Ghatak, Tata McGraw Hill (2008)
5. Fiber Optics and Optoelectronics, R P Khare, Oxford University Press (2015)
6. Concepts of Modern Physics, Arthur Beiser, Tata McGraw-Hill, 7th Edition, (2015).
7. Fundamentals for Molecular Spectroscopy, 4th Ed., C. N. Banwell and E. M. McCash, McGraw Hill Education (2017).

PHY 10504: Numerical and Computational Physics

Credits: 4
Hours : 60 hours

Course Objective

This course provides an introduction to the numerical techniques and computational methods used in physics. Applications will be drawn from various areas of physics, such as classical mechanics, quantum mechanics, and statistical physics.

Course Outcome

1. To be able to apply computational techniques to solve physics problems.
2. To be able to analyze and interpret simulation data.
3. To develop an understanding of numerical methods used in physics.

Module I Programming language: Introduction to Python/Matlab/Octave programming, IDEs for programming, variables, input/output, loading and saving data, loops, branches and control flow, matrix and array operations.Sub programs, array of dimensional variables, subroutines, functions, modular programming, built-in functions and modules. Data Visualization; Plotting functions, scatter plot, 2D plots, Heatmaps, Histograms

Module II Solving algebraic equations: Newton-Raphson method, Application to time of flight calculation. Finding the minimum/maximum of a function, interpolation, linear algebra and Fourier series/transform. Numerical differentiation: Calculating first and second derivative numerically. Numerical integration: Trapezoidal and Simpson's rule.

Module III Solving ordinary differential equations: Eulers method, RK method, Application to simple harmonic motion, motion in a viscous medium, projectile motion. Partial differential equations (PDEs), Finite difference methods, Application to the heat equation.

Module IV Data analysis techniques, Curve fitting, Monte Carlo methods, obtaining statistics from data, Random number generation, Simulating experimental data - simple pendulum experiment, trajectory of a projectile, Application to calculating integrals, Application to statistical mechanics

Text Books:

1. Computational Physics by Mark Newman and Gergely Toth.
2. An Introduction to Computational Physics by Tao .
3. Numerical Methods for Physics by Alejandro L. Garcia.

Semester VI

PHY 10601: Basic Solid State Physics

Credits: 4
Hours : 60 hours

Course Objective

Understand the basics of crystal structure, representation of crystals in the reciprocal space, different type of bonding, band theory and dielectric, magnetic and super conducting properties of materials.

Course Outcome

1. Understanding the crystal structure, reciprocal lattice and x-ray diffraction of crystals.
2. Understanding the crystal binding, lattice vibration and specific heat of solids.
3. Understanding the band theory and free electron theory.
4. Understanding the magnetic, dielectric and superconducting properties of solids.

Module I Crystalline and amorphous phase, Crystal structure; periodicity, lattices and basis, fundamental translation vectors, primitive and non-primitive unit cell, Winger-Seitz cell, Diffraction of waves in crystal, Bragg law, reciprocal lattice, diffraction condition in reciprocal space, Laue equation, Seven Crystal system in 3D, Miller indices for plane Brillouin zone, Reciprocal lattice to SC, BCC and FCC lattice.

Module II Structure of solids Different types of bonding - ionic, covalent, metallic, van der Waals and hydrogen, Lennard Johns potential, cohesive energy, Madelung energy, Lattice vibrations Elastic and atomic force constants; Dynamics of a chain of similar atoms, acoustic mode; Einstein's and Debye's theories of specific heats of solids.

Module III Free electron theory of metals, mobility and conductivity, Wiedemann-Franz law, Hall effect in metals. Band theory of solids, Periodic potential and Bloch theorem, effective mass, Kronig-Penny model, energy band structure. Band structure in conductors, direct and indirect semiconductors, and insulators (qualitative discussions).

Module IV Magnetic properties of materials Dia, para and ferro-magnetic properties of solids. Langevin's theory of diamagnetism and paramagnetism, Curie's law, Ferromagnetism: spontaneous magnetization and domain structure; temperature dependence of spontaneous magnetisation; Curie-Weiss law, explanation of hysteresis. Superconductivity, effect of magnetic field, Type-I and type-II superconductors, Isotope effect. Meissner effect. Heat capacity. Energy gap. Ideas about High-Tc superconductors. 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. Introduction to Solid State Physics (8th Edition), Charles Kittel, Wiley (2004).
2. Solid state physics, Ashcroft, Neil W. and Mermin, N., Brooks/Cole (1976).

3. Elementary Solid State Physics: Principles and Applications, Ali Omar, Pearson (1993).
4. Solid State Physics- Structure and properties of Materials, MA Wahab, Narosa Publications
5. Solid State Physics, SO Pillai, New Age International(P) Limited Publishers
6. Solid State Physics, Dekker, A. J., Macmillan (2000).
7. The Oxford solid state basics, Simon, Steven, Oxford University Press (2004).

PHY 10602: Basic Nuclear Physics and Applications

Credits: 4
Hours : 60 hours

Course Objectives

The course aims to develop an understanding of the basic concepts of nuclear physics and particle physics. Also, the students will get an idea of different types of nuclear radiation, their interactions with matter, and their applications in our life.

Course Outcomes

After completing this course the students will be able to

1. Understand the basic properties of atomic nucleus, binding energy and elements of nuclear models (Module 1)

2. Familiarise the different types of decays and its properties. (Module 2)

3. Summarize the interaction of radiation with matter and its applications. (Module 3)

4. Classify different types of accelerators and familiaries the elementary particles and its properties. (Module 4)

Module I Introduction and Basic concepts: The nucleus and its constituents, the N-Z chart, Nuclear mass, Radius, Density, Spin, Parity, Stable Nuclei, Binding energy, Nuclear potential and energy levels, Semi empirical (liquid drop) model, Evidence for shell structure, magic numbers, Nuclear shell model (with the harmonic oscillator potential), spin-orbit coupling.

Module II Radioactivity, Radioactive decay law, Half-life, Types of decays, Alpha emission, Beta emission and electron capture, Gamma emission and internal conversion, Natural Radioactivity, radioactive decay chains, Radioactive Dating, Nuclear Collisions, Cross section, differential cross section and reaction rate, Nuclear reactors and energy production, Breeder reactors.

Module III Interaction of radiation with matter: Heavy charged particles interactions, Bethe-Bloch formula, Energy dependence, Bragg curve, Stopping medium dependence, Absorbed dose, equivalent dose, Gamma rays interactions, photoelectric effect, Compton scattering, Pair production, Applications in tracing, material modification, sterilization, material modification, neutron activation analysis, Diagnostic Nuclear Medicine and Therapeutic Nuclear Medicines: CT, PET, SPECT, MRI.

Module IV Linear and circular accelerators, Interactions and Particles, Leptons, Hadrons, Quarks, Conservation laws and symmetries, Conservation of energy and mass, Conservation of linear momentum and angular momentum, Conservation of Baryon and Lepton numbers, Conservation of strangeness, Conservation of isospin.

Text Books:

1. J. S. Lilley, Nuclear Physics: Principles and Applications, John Wiley (2001).
2. Kenneth S. Krane, Introduction to Nuclear Physics, John Wiley (2008).
3. The particle hunters (2nd Revised Edition), Yuval Ne'eman & Yoram Kirsh, Cambridge University Press (1996).

Reference Books:

1. Herald A. Engel, Introduction to Nuclear Physics, Addison Wesely (1967).
2. Cohen B. L., Concepts of Nuclear Physics, Tata McGraw Hill (2008).

Semester VII

PHY 10701: Mathematical Physics

Credits: 4
Hours :60

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 them in 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 Poisson equation by the method of separation of variables.
6. Solve algebraic equations, differential equations and calculate definite integrals numerically.

Module I

Review of vector calculus. Orthogonal curvilinear coordinates, cylindrical and spherical polar coordinates. Vector integration and integral theorems. Tensor analysis: Contravariant and covariant vectors, Basic operations with tensors, Quotient law, The line element and metric tensor.

Module II

Review of Complex numbers and 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.

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 :60 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 equations form it. Symmetry properties and Noether's theorem. Application of Lagranges equation to Central force problem - equivalent one dimensional problem - classification of orbits - the differential equation for 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 : 60 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, conservation laws and boundary conditions of electromagnetic fields at an interface.
- Application of Maxwell's equations for the study of propagation of electromagnetic waves in various media.
- To understand and develop the theory of wave guides and electromagnetic radiation phenomena.
- To look at the close relationship between electromagnetic phenomena and special theory of relativity.

Course Outcomes

1. Will get familiarized with the various boundary value problems and learn different techniques for 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 electromagnetic radiation 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 near a grounded conducting sphere-point charge near a charged insulated conducting sphere - conducting sphere in an uniform electric field.

Module II

Laplace equation in spherical polar coordinates- boundary value problem with azimuthal symmetry. Maxwell's equations. Vector and scalar potentials - gauge transformations - Lorentz gauge, Coulomb gauge. Poynting's theorem and conservation of energy and momentum, complex Poynting vector. Boundary conditions for the electric and magnetic fields at an interface - Plane electromagnetic wave in a non-conducting medium, linear and circular polarization, reflection and refraction at a dielectric interface, polarization by reflection and total internal reflection.

Module III

Waves in conducting or dissipative medium-skin depth. Cylindrical cavities and wave guides, metallic wave guides, modes in a rectangular wave guide, resonant cavities. Green's function for wave equation. Simple radiating systems- fields and radiation of a localized oscillating source - electric dipole field and radiation, magnetic dipole and electric- quadrupole fields.

Module IV

Review: *Special theory of relativity - Postulates of relativity, Lorentz transformations, four vectors, addition of velocities, four velocity, relativistic momentum and energy, mathematical properties of space-time, matrix representation of Lorentz transformation.*
Dynamics of relativistic particles. Lagrangian and Hamiltonian of relativistic charged particle, motion in a uniform static electric and magnetic fields, magnetism as a relativistic phenomenon, transformation of the electromagnetic field, electromagnetic field tensor, covariant formulation of Maxwell's equations.

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

Credits: 4
Hours : 60 hours

Course Objectives

The course aims to develop an understanding of the theoretical framework of Quantum Mechanics and its applications.

Course Outcomes

- Solve classic problems in Quantum Physics like the harmonic oscillator, the Hydrogen atom and scattering.
- Learn the quantum theory of angular momentum.
- Learn to apply perturbative approach towards solving difficult problems approximately
- Learn to solve time-dependent problems in quantum mechanics.

Module I

The Harmonic Oscillator - operator formalism; Free particle in 3-dimensions: spherically symmetric solution; Schrodinger equation in presence of central Potential; Orbital angular momentum: eigenvalues and eigenfunctions of of L2 and Lz ; Hydrogen Atom - eigenfunctions and eigenstate; Scattering: Cross Section,Amplitude and Differential Cross Section, Scattering of spinless Particles, The Born Approximation, Validity of the Born Approximation.

Module II

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 III

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, Tunneling through a potential barrier.

Module IV

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.

Text Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009.
2. J J Sakuari, Modern Quantum Mechanics, 3rd edition, Cambridge University Press, 2020.
3. Introduction to Quantum Mechanics, D. Griffiths, 2nd Edition, Cambridge University (2017). (Module 2)

Semester VIII

PHY 10801: Statistical Physics

Credits: 4
Hours : 60

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 behavior of a system. A short introduction to the world of non-equilibrium statistical physics is also given at the end of the course.

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 equilibrium properties of physical systems.
3. For a given ideal system, derive various macroscopic quantities - either using a classical or a quantum 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 interaction 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 with a heat reservoir, Canonical ensemble and the Boltzmann distribution, Partition function and Free energy, Paramagnetism, Ideal gas in canonical ensemble - mean energy and mean pressure, harmonic oscillator, Grand Canonical ensemble.

Module III

Canonical distribution in the classical approximation: Phase space of classical systems, Ideal gas, entropy of mixing and Gibbs paradox, Maxwell velocity distribution, harmonic oscillator, The equipartition theorem and its applications, Liouville's theorem.

Module IV

Statistical physics of ideal quantum gases: Ideal Fermi gas at zero and non-zero temperatures, Fermi-Dirac and Bose-Einstein integrals, Ideal Bose gas - Bose-Einstein condensation, Density operator. Interacting systems: 1D Ising model, Mean field approach, Phase transitions, Critical point and critical exponents, Universality, Renormalization group approach (Qualitative ideas).
Brownian Motion, Random walk in 1D, Einstein's derivation of the diffusion equation, Langevin and Fokker-Planck equations.

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 10802: Atomic and Molecular Spectroscopy

Credits: 4
Hours : 60 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 atomic spectra 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 and electric fields. (Module 1)
3. Explain the contributions of transitions between rotational, vibrational and electronic states to the spectra of diatomic molecules. (Module 2)
4. Describe how IR and Raman spectroscopic techniques are used in molecular structure determination (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 working principle 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 and instrumentation for microwave spectroscopy. The vibrating diatomic molecule - simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator - CO molecule. Interaction of rotation and vibrations, the vibrations of polyatomic molecules and their symmetry, the influence of rotation on the spectra of linear molecules - Electronic spectra of diatomic molecules - Born-Oppenheimer approximation, vibrational coarse structure - progressions. Intensity of vibrational transitions – the Franck-Condon principle. Dissociation energy and dissociation products. Rotational fine structure of electronic-vibrational transitions - the Fortrat diagram. Predissociation.

Module III

Raman effect - classical theory, elementary quantum theory, pure rotational Raman spectra - linear molecules, vibrational Raman spectra polarization of light and Raman effect, techniques and instrumentation of Raman and IR spectroscopy, structure determination by IR and Raman spectroscopy-simple examples, fundamentals of SERS. Nuclear and electron spin - interaction with applied magnetic field, population of energy levels Larmor procession, NMR: NMR of hydrogen nuclei - chemical shift, techniques and instrumentation for NMR spectroscopy, medical applications of NMR - ESR spectroscopy - g factor - fine and hyperfine structure, double resonance, Basic idea of Mossbauer Spectroscopy- Recoilless emission and absorption.

Module IV

Einstein's coefficients, Laser fundamentals and fabrication- active medium, pumping 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, McGraw Hill 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).

Semester IX

PHY 10901: Nuclear and Particle Physics

Credits: 4
Hours : 60 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 in terms of elementary particles. (Module 4)

Module I

Nuclear properties: Review of basic concepts, nuclear radius, shape, spin, parity, electric multipole moments, nuclear magnetic moments, Schmidt model, nuclear binding energy, properties of nuclear force, Meson theory of nuclear forces
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, Fermi-gas model, Semi empirical mass formula, Shell model, Spin-Orbit potential, Valance nucleons, Nilsson Model, Collective Models, 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, Nuclear fusion.

Module III

Nuclear decays: barrier penetration and alpha decay, Gamow's theory, Geiger Nuttall law, beta decay, Fermi's theory of beta decay, Kurie plot, Fermi and Gamow-Teller transitions, Neutrino mass, parity violation in beta decay, gamma decay, multipole moments and selection rules.
Detection of nuclear radiation: Interaction of radiation with matters, properties of detectors, gas-filled counters, scintillation detectors, semiconductor detectors, Detector performance, 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, The eight fold way, the Sakata Model, the quark model, coloured quarks and gluons, reactions and decays in the quark model, c, b and t quarks, quark dynamics.

Text Books:

1. Nuclear Physics (2nd Edition), V. Devanathan, Narosa Publishing House, New Delhi (2011).
2. Introductory Nuclear Physics (3rd Edition), Kenneth S. Krane, Wiley (1987).
3. The particle hunters (2nd Revised Edition), Yuval Ne'eman & Yoram Kirsh, Cambridge University Press (1996).

Reference Books:

1. Introduction to Nuclear Physics (1st Edition), Harald A. Enge, Addison Wesley (1996).
2. Concepts of Nuclear Physics, B. L. Cohen, McGraw-Hill Inc., US (1971).
3. Nuclear Physics: Theory and Experiment, R. R. Roy and B.P. Nigam, Newagepublishers (1996).
4. Theoretical Nuclear Physics, J. M. Blatt and V. F. Weisskopf, Springer-Verlag New York (1979).
5. An Introduction to Nuclear Physics (2nd Edition), S. B. Patel, New Age International (2011)
6. Introduction to Elementary Particles (2nd Revised Edition), David Griffiths, Wiley VCH (2008).

PHY 10902: Advanced Solid State Physics

Credits: 4
Hours : 60 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 will 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 heat of solids. (Module 1).
3. The details about the vibrations in the atomic chain and the applications of scattering experiments 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 the Free Electron Model.

Module II

Vibrations of a One-Dimensional Mono-atomic Chain - Phonons-Crystal Momentum , Vibrations of a One-Dimensional Diatomic Chain - The Reciprocal Lattice in Three Dimensions - General Brillouin Zone Construction - Electronic and Vibrational Waves in Crystals in Three Dimensions - Wave Scattering by Crystals - Equivalence of Laue and Bragg conditions - Scattering Amplitudes - Systematic Absences - Geometric Interpretation of Selection Rules - Methods of Scattering Experiments - Powder Diffraction - Scattering in Liquids and Amorphous Solids.

Module III

Electrons in Solids - Electrons in a Periodic Potential - Kronig-Penny Model- Bloch's Theorem- Nearly Free Electron Model - Tight Binding Model - Energy Bands in One Dimension - Energy Bands in Two and Three Dimensions - Introduction to Electrons Filling Bands - Multiple Bands - Band-Structure Picture of Metals and Insulators - Optical Properties of Insulators and Semiconductors - Direct and Indirect Transitions - Optical Properties of Metals - Optical Effects of Impurities - Electrons and Holes - Doping - Impurity States - Statistical Mechanics of Semiconductors -Band Structure Engineering - Designing Band Gaps - Non-Homogeneous Band Gaps.

Module IV

Magnetism and Mean Field Theories - Hund's Rules - Coupling of Electrons in Atoms to an External Field - Free Spin (Curie or Langevin) Paramagnetism - Larmor Diamagnetism - (Spontaneous) Magnetic Order - Ferromagnets - Antiferromagnets - Ferrimagnets - Macroscopic Effects in Ferromagnets: Domains - Domain Wall Structure and the Bloch/ Neel Wall - Hysteresis in Ferromagnets.
Superconductors - Type-I and Type-II superconductors - Meissner effect - BCS theory (qualitative) - High temperature superconductors - applications - Josephson effect.

Text Books:

1. Solid state physics, Ashcroft, Neil W. and Mermin, N., Brooks/Cole (1976).
2. The Oxford solid state basics, Simon, Steven, Oxford University Press (2004).
3. Introduction to Solid State Physics (8th Edition), Charles Kittel, Wiley (2004).

Reference Books:

1. Solid State Physics, Dekker, A. J., Macmillan (2000).
2. 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).

Discipline Specific Elective Courses

06: 2D Materials

Course Code: 06
Credits: 4
Hours : 60

Course Objective

To introduce the field of 2D materials, different classes and their properties.

Course Outcome

1. Familiarise with low dimensional structures and their properties.
2. Learn about 2D material families (Graphene, 2D transition metal chalcogenides/carbides).
3. Familiarise with properties and applications of 2D materials.
4. 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 - Opening Gaps in Graphene - Electronic Properties of Graphene. Relationship between Dispersions of the 1-D and 2-D Systems, Metal contacts to graphene- Chemical bonding of metal with graphene-electrochemical equalization- orbital hybridization-characteristics of metal contact to graphene- applications of Graphene.

Module II

Introduction to 2D transition metal dichalcogenides (TMDC). Atomic and electronics Structure: Structure of individual triple layers – Bulk structure of polymorphs–Van der Waals Interlayers bonding-Electronic Structures. Raman and electronic spectra of TMDCs. Synthesis of Transition Metal Dichalcogenides – Top down Method:- Mechanical Exfoliation –Liquid Exfoliation-Electrochemical Exfoliation – Bottom up Method:-Chemical Vapour (CVD) – Pulsed Laser Deposition (PLD). Properties: Mechanical Properties-Thermal conductivity –Thermoelectric properties- optical properties-applications of TMDC.

Module III

Introduction to 2D transition metal carbides and nitrides, The M n+1 AX n phases- precursors for MXenes, Top down MXene synthesis (selective etching), Bottom up synthesis of 2D transition metal carbides and nitrides, Effect of synthesis methods on the structure and defects of two dimensional MXenes, MXene surface chemistry, Techniques of MXene delamination into single flakes, MXene films, coatings and bulk processing, Predicted electronic, magnetic, mechanical and optical properties of MXenes- applications of MXenes.

Module IV Two dimensional topological materials, Dirac/Weyl equation, topological insulators, Weyl semimetals, topological superconductors, electron transport in two dimensional topological materials, Weyl fermions in condensed matter systems, Fermi arcs, intrinsic anomalous Hall effect, magnetic breakdown and Klein tunnelling effect, Landau level collapse effect - applications of 2D topological materials.

Text Books :

1. Munarriz Arrieta, Modelling of Plasmonic and Graphene Nanodevices, Springer 2014.

2. S.V. Gaponenko, Optical properties of Semiconductor Nano crystals, Cambridge university press 1998.

3. Vasilios Georgakilas, Functinalization of Graphene, Wiley - VCH Verlag GmbH & Co. KGaA, 2014.

4. Two-DimensionalTransition-Metal Dichalcogenides, Alxander V Kolobov, Junji Tomenaga , https://www.springer.com/series/856.

5. Y. P. Venkata Subbaiah, K. J. Saji, and A. Tiwari, 'Atomically Thin MOS2: A Versatile Non-graphene 2D Material ,' Adv. Funct. Mater., vol. 26, no. 13, pp. 2046–2069, 2016, doi: 10.1002/adfm.201504202.

6. Advanced 2D materials , Editors : Ashutosh Tiwari,Mikeal Syvajarvi DOI:10.1002/9781119242635.

7. 2D Metal Carbides and Nitrides (MXenes), Structure, Properties and Applications, Editors: Anasori, Babak, Gogotsi, Yury (Eds.)

8. Transport in two-dimensional topological materials: recent developments in experiment and theory (Dimitrie Culcer et al 2020 2D Mater. 7 022007).

9. Weyl semi-metals : a short review Sumathi Rao Harish-Chandra Research Institute, Chhatnag Road, Jhusi, Allahabad 211 019, India.

10. Quasiparticle interference on type-I and type-II Weyl semimetal surfaces: a review Hao Zheng & M. Zahid Hasan.

07: Advanced Electronics

Course Code: 07
Credits: 4
Hours : 60 hours

Course Objectives

Advanced level knowledge in Electronics is essential to understand the working of computers, telecommunication systems, sophisticated analytical instruments, and other electronic appliances in our everyday life. After completion of this course, the students will be able to design different digital and analog electronic circuits for specific applications like register, counter, analog to digital converter, integrator, differentiator, comparator, waveform generators 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 using universal-NAND gates. (Module 1)
2. Understand the primary applications of the operational amplifier as an adder, subtractor, differentiator, 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, serial and parallel registers, Tristate switches, Tristate buffer registers, Bus organization in computers, Counters, Synchronous and Asynchronous counters, Ripple counters, Ring counter, Timing diagram, Fundamentals of D/A conversion,-Accuracy and resolution -ADC/DAC chips, Flash Converters.

Module 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 equations – 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 Demodulation 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, Prentice 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 University press (1998).

08: Advanced Magnetism and Magnetic Materials

Course Code: 08
Credits: 4
Hours : 60

Course Objectives

1. A postgraduate level course in Advanced Magnetism and Magnetic Materials will help in student having a thorough understanding of magnetism in condensed matter.

2. This course will equip the student with required prerequisites to proceed with a Ph.D. program in condensed matter physics or with a scientific position in magnetic materials industry.

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 physics or 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 magnetic 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 magnetization - 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 substances & 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 ferromagnetism - Ferromagnetic domains - Observing domains - The occurrence of domains - Domain walls - Magnetization and hysteresis Antiferromagnetism: Neutron diffraction - Weiss theory of antiferromagnetism - 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 University Press, 2003 [Module 1,2,3 and 4]
2. Physics of Magnetism and Magnetic Materials - K.H.J Buschow and F.R De Boer, Kluver Academic Publishers, London, 2003 [Module 4]
3. Nanoscale Magnetic Materials and Applications - Editors: J.Ping Lu, Eric Fullerton, Oliver Gutfleish, David J. Sellmyer, Springer, 2009 [Module 4]

Reference Books:

1. Introduction to Magnetic Materials - B.D. Cullity and C.D. Graham. Addison-Wesley, 1972.
2. Introduction to Magnetism and Magnetic Materials - D. Jiles. Chapman & Hall, 1996.
3. Molecular Quantum Mechanics - P.W. Atkins. Oxford University Press, 1999.

09: Advanced Mathematical Physics

Course Code: 09
Credits: 4
Hours : 60

Course Objective

To equip the students to use some of the advanced 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 equations and 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 general relativity.
6. Understand basics of stochastic differential equations.

Module I

Review of solving first and second order ordinary differential equations. Review of solving first order partial differential equations. Sturm - Liouville theory: eigenvector expansions; Hilbert spaces; self-adjoint operators; eigenfunction expansions; existence of eigenvalues and completeness of eigenfunctions; spectral theory. Classification of second order PDE s hyperbolic, parabolic and elliptic equations. Green function methods for PDEs, Laplace transform and Fourier transform solutions.

Module II

Contravariant and covariant tensors - transformation rules - direct product, con-traction, quotient rule. Metric tensor - lowering and raising of indices - covariant derivatives -Christoffel symbols. Riemann curvature tensor.

Module III

Weiner process and white noise, Stochastic integrals, Ito calculus, stochastic differential equations, The Fokker-Plank equation, Brownian motion, numerical simulations.

Module IV

Definition of a group- Cyclic groups -Group multiplication table - Isomorphic groups - Group of permutations and Cayley's theorem - Subgroups and cosets - Conjugate classes and invariant subgroups - Group representations - symmetry group D2 and D3 - One-dimensional unitary group U(1) Orthogonal groups SO(2) and SO(3) - SU(n) groups.

Text Books :

1. Mathematical Methods for Physicists Paperback (7th Edition), Arfken, Elsevier (2012).
2. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).
3. Jon Mathews and Robert Walker,Mathematical Methods of Physics, Benjamin/Cummings Publishing Co. ISBN 0805370021.

Reference Books :

1. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2001).

10: Advanced Raman Spectroscopy

Course Code: 10
Credits: 4
Hours : 60
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 applications in industry, material science, medicine and forensic science etc..

Course Outcomes

After completion of this course, the students will have good fundamental understanding, instrumental aspects, and analysis of materials using Raman spectroscopy.

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, Academic press, Elsevier.

11: Advanced Solid State Physics-II

Course Code: 11
Credits: 4
Hours : 60 hours

Course Objectives

To make the students learn modern developments in the field of condensed matter physics particularly to those who wish to do research in this area.

Course Outcomes

1. Understand the different perspectives of the carrier absorption and its transport properties.
2. Familiarize with the theoretical tools like density of states etc.
3. 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

12: Applied Vibrational Spectroscopy

Course Code: 12
Credits: 4
Hours : 60

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 softwares for the computation of vibrational spectra- Vibrational spectral anaylysis of Inorganic compounds containing water- Sulphate- phosphate -bromate- carbonate- complexes of sulfate, carbonate, and related ligands-Organic compounds - Carbon nanotubes- graphite- Oxide nanomaterials- Identification of hydrogen bonded system- 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.

13: Astrophysics

Course Code: 13
Credits: 4
Hours : 60 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 diagram etc.
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 publishing house, 2001.
2. Astrophysics - Stars and Galaxies, K. D. Abhyankar, University Press, 2001.

Reference Books :

1. M.Schwarzschild:Stellar Evolution
2. S.Chandrasekhar:Stellar Structure
3. Theoritical Astrophysics (Vols.I,II,III) - T. Padmanabhan (CUP)
4. Menzel,Bhatnagar and Sen:Stellar Interiors.
5. Black Holes, White Dwarfs and Neutron Stars - S.L.Shapiro and S.A.Teukolsky (John Wiley, 1983)
6. Cox and Guili:Principles of Stellar Interiors - Vol.I and II.
7. R.Bowers and T. Deeming:Astrophysics (John and Barlett.Boston)

14: Biophysics

Course Code: 14
Credits: 4
Hours : 60

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 cultures(Qualitative treatment)-Sedimentation of cell cultures.

Module III

Nerve impulses-Neurotransmitters and synapses-Passive and active transports in dendrites- Mechanical properties of biomaterials (Qualitative treatment)-Youngs, shear modulus and Poisson ratio-electrical stresses in bilological membranes-Mechanical effects of microgravity during space flight, fundamentals of biomagnetic field sources- fundamentals Passive electrical properties of living cells.

Module IV

Light absorption in biomolecules-Bioimpedence-Time harmonic current flow- Dielctric spectroscopy-Deybe relaxation model-Cole equation-Fundamentals of protein folding, basic techniques for protein folding, protein crystallization, Vapor diffusion- Sitting drop method- Hanging drop method- Basics of structure determination of proteins with X-ray crystallography- sample handling techniques.

Text Books:

1. Introductory biophysics perspectives on the living state J.Claycomb, J.Quoc P.Tran, Jones & Bartlet Publishers.

2. Biophysics; N. Arumugam, V. Kumaresan, Saras publication; SBN : 9789384826673.

3. Biological Physics; Philip Nelson; W. H. Freeman & Company ; 2013.
4. Protein Folding; Charis Ghelis; Academic Press;1982.
5. Preparation and Analysis of Protein Crystals; McPherson, A. 1982, John Wiley & Sons.
6. Terese M. Bergfor's, Protein Crystallization Techniques, Strategies and Tips, International University Line, 1999.

15: Complex Networks

Course Code: 15
Credits: 4
Hours : 60
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 will be able to

1. Demonstrate an understanding of the terminology, concepts and principles of the study of complex 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 and applications.

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).

16: Computational Physics

Course Code: 16
Credits: 4
Hours : 60 hours

Course Objective

To introduce students to numerical methods and computational techniques for solving problems in various areas of Physics and Mathematics. 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 equation.

Module IV

Molecular dynamics: Theory, Integration methods, Measurement of static and dynamic properties. Langevin dynamics simulations for Brownian motion. The Monte Carlo method: Probability distribution functions, random number generation, Monte Carlo integration, importance sampling, Random walks and the Metropolis Algorithm, Application to model systems.

Text Books :

1. An Introduction to Computer Simulation Methods: Applications to Physical Systems - Gould, Tobochnik & Christian, 3rd Edition, Addison Wesley (2006).
2. Basic Concepts in Computational Physics - Stickler and Schachinger, Springer (2013).
3. Computational Physics: Problem Solving with Computers - Landau and Paez, 2nd Edition, John Wiley & Sons (2007).
4. Computational Physics - Nicholas J Giordano and Hisao Nakanishi, 2nd Edition, Pearson-Prentice Hall (2006).
5. Computational Physics - P. Scherer, Springer (2010).

Reference Books :

1. An Introduction to Numerical Analysis - K.E. Atkinson, 2nd Edition, John Wiley & Sons (1989).
2. An Introduction to Computational Physics - Tao Pang, 2nd Edition, Cambridge University Press (2006).

17: Crystal Growth

Course Code: 17
Credits: 4
Hours : 60 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 - Reduction method method - Growth of biologically important crystals.

Module IV

Crystallization of hydroxy apatite - Protein crystallization techniques - Hanging Drops-Sitting Drops-Sandwich Drops-Reverse Vapor Diffusion- pH Gradient Vapour Diffusion-Practical Tips for Vapuor Diffusion –Dialysis-Batch Techniques –Micro batch –Protein Samples- Precipitants- Buffers and pH –Temperature-Crystallization Strategies-A Flexible Sparse Matrix Screen-An Alternative to Sparse-Matrix Screens-Reverse Screen- Imperial College Grid Screen- Seeding-Macro seeding-bio-crystallization, protein crystallization and characterization of biological crystals.

Text Books:

1. J.C. Brice, Crystal growth processes, John Wiley and sons, New York, 1986.
2. P.Santhana Raghavan and P.Ramasamy, Crystal Growth Processes and Methods, KRU Publications, Kumbakonam (2000).
3. A. Laudise, The Growth of single crystals. Prentice Hall, 1970.
4. B.Pamplin, Crystal Growth. Volume 16, Pergamon Press.1973.
5. F.F. Abraham, Homogenous nucleation theory, Advances in Theoretical Chemistry, Academic Press, New York, 1974.
6. R.F. Strickland, Kinetics and Mechanism of Crystallization, Academic Press, New York, 1968.
7. Sujata V. Bhat, Biomaterials, Narosa Publising House, New Delhi,2002
8. A.Ducruix and R.Giege, Crystallization of Nucleic Acids and Proteins A Practical Approach, Oxford University Press, England, 1992
9. Terese M. Bergfor's, Protein Crystallization Techniques, Strategies and Tips, International University Line, 1999.

18: Elementary Astronomy

Course Code: 18
Credits: 4
Hours : 60

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 properties.
3. Get a reasonable knowledge about the formation of stars, and objects like white dwarf, black hole etc.

Module I

Celestial Sphere and Time : Constellations. The celestial sphere. Equatorial, ecliptic system of coordinates. Seasons, Sidereal, Apparent and Mean solar time. Calendar. Julian date. Stellar Distances and Magnitudes : Distance scale in astronomy. Determination of distances to planets and stars. Magnitude scale. Atmospheric extinction. Absolute magnitudes and distance modulus. Colour index.

Module II

Theories of formation of the Solar System, The Sun: Photosphere, chromosphere and corona of the Sun. Sun spots and magnetic fields on the sun. Solar activity, solar wind.
Planets and their Satellites : Surface features, atmospheres and magnetic fields of Earth, Moon and Planets. Satellites and rings of planets. Asteroids, Meteors, Meteorites and Comets.

Module III

Stars : Basics of Star formation & Evolution. The HR diagram. Pre-main sequence contraction, main sequence stage and formation of super dense objects - White dwarfs, Neutron stars & Pulsars. Black holes.

Module IV

The Milky Way Galaxy & Galaxies beyond : Structure of the Milky Way Galaxy Galactic and globular clusters. Inter Stellar Matter, Position of our Sun and its motion around the galactic centre. Rotation of the Galaxy and its mass.
Extragalactic Systems : Hubble's classification of galaxies and clusters of galaxies. Galaxy interactions, Elements of Astrobiology.
Introduction to Cosmology : The expanding universe. Big Bang and Steady State models of the universe. Dark matter.

Text books:

1. H. Karttunen, P Kroger, H Oja, M Poutanen & K. J. Donner editors. Fundamental Astronomy, 5^{th} Edition, Springer-Verlag (2007).
2. Baidyanath Basu: Introduction to Astrophysics, PHI, 2nd ed. (2013)

References :

1. W.M.Smart: Foundations of Astronomy, Longmans (1965)
2. Frank H. Shu: The Physical Universe-An Introduction to Astronomy, Univ Science Books (1981)
3. K D Abhyankar: Astrophysics of the Solar System, Universities Press (1999)
4. Horneck and Rettberg: Complete Course in Astrobiology, Wiley (2009)
5. Introduction to cosmology, J V Narlikar, Cambridge University Press; 3 edition (2002)

19: Femtosecond Lasers and Applications

Course Code: 19
Credits: 4
Hours : 60

Course Objectives

The course is on intense femtosecond 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 condensed media.
3. Evaluate Research Opportunities and technology of intense field interaction physics.
4. Develop lifelong learning skills through research.

Module I: Femtosecond Lasers

Laser basics- Femtosecond laser oscillators and Amplifiers - Mode locking - Kerr lens mode locking - Group velocity dispersion– Chirped Mirrors – Pulses-Time bandwidth product - bandwidth limited pulses – Pulse propagation - nonlinear refractive index - self phase modulation of pulses - supercontinuum – Research Review.

Module II: Femtosecond Amplifiers and interaction with matter

Ti: Sapphire laser - chirped pulse amplification - regenerative amplifiers - multipass amplifiers – Fibre lasers - femtosecond pulse measurements - intensity autocorrelation - cross correlation - FROG and SPIDER - Ionization of gases - Multiphoton ionization - Tunnel ionization - Keldysh Approximation - Over the barrier ionization – Research Review.

Module III: Femtosecond laser produced plasma

Average and Peak power of the laser – Gaussian beams - Focusing - M 2 value - Focused laser intensity-Basics of a plasma – Plasma density, plasma temperature, Debye length plasma frequency, critical density – Dispersion relation – Laser - plasmas - Inverse bremsstrahlung and collisional absorption – resonance absorption (basics) - Brunel heating (basics) – Radiations – Free-free, free- bound and line radiations – Research Review.

Module IV: Applications of femtosecond lasers

Transient absorption spectroscopy - THz radiation - Femtosecond micromachining - Two photon polymerization and direct laser 3D printing - High harmonic generation (re-collision picture) – Attosecond pulses - X-ray sources from laser interactions – Water window radiation – Laser Wakefield acceleration (LWFA) – Inertial Confinement Fusion – Research Review.

Text Books: Modules 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)

Module 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)

Module 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.

20: Fundamentals of Photovoltaics

Course Code: 20
Credits: 4
Hours : 60

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 technologies 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

21: Gravitation and Cosmology

Course Code: 21
Credits: 4
Hours : 60

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 of relativity. 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, cosmological redshift, open, closed and flat universes, matter dominated and radiation dominated universes, Particle horizon and event horizon, primordial nucleosynthesis, CMBR, Flaws of the FRW model. Jean's mass in the expanding universe, evolution of the Jean's mass. Dark matter, recent acceleration of the universe, Dark energy. (only introductory ideas.)

Text Books:

1. Gravitaion and Cosmology, S. Weinberg, ,John Wiley & Sons (1972)

2. A First Course in General Relativity, Schutz, Bernard. New York, NY: Cambridge University Press, 1985. ISBN: 9780521277037.

3. Introduction to cosmology, J. V. Narlikar, Cambridge University Press, 3rd edition (2002)

Reference Books:

1. Gravity, J. B. Hartle, Pearson Education.(2003).

2. Gravitation, Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler,(1973).

3. Gravitation - Foundations and Frontiers , T. Padmnabhan, cambridge University Press, New York (2010)

22: Laser and Nonlinear Optics

Course Code: 22
Credits: 4
Hours : 60

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 (Population Inversion - Stimulated emission - Einstein Coefficients) - Laser , Ruby Laser.

Module II

Optical Resonant Cavities , Longitudinal and Transverse modes , Properties of Gaussian laser beams , Spatial frequencies , Abbels theory of image formation , Spatial Filtering phase contrast Imaging.

Module III

Pulsed high power lasers , Q switching , Methods of producing Q switching , Mode locking , Methods of producing mode locking , Pulse shortening by self phase modulation, Group velocity dispersion, gratings or prisms , femto-second lasers , basic ideas of chirped pulse amplification and regenerative amplifiers.

Module IV

Nonlinear Optics , Nonlinear Wave equation , Optical rectification , Harmonic Generation , Phase matching , Third Harmonic generation , Parametric oscillator , B integral - self focusing , Two photon absorption.

Text Books:

1. Hecht, E and A R Ganesan, Optics 4th Ed., Pearson (2019).
2. Silfvast, W T, Laser Fundamentals 2nd Ed., Cambridge University Press (2008)
3. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press (2003).

References

1. Ajoy Ghatak, Optics 5th Ed., McGraw Hill.
2. Bahaa E . A. Saleh and Malvin Carl Teich , Fundamentals of Photonics 2nd Ed., Wiley (1991)
3. Laud, B.B. - Lasers and Nonlinear Optics, New Age International (P) Limited (1991)

23: Light Sources and Detectors

Course Code: 23
Credits: 4
Hours : 60

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 detectors in ultraviolet-visible-infrared regions of the electromagnetic spectrum.
3. Demonstrate the safety procedures to be taken while setting up experiments with advanced optical 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), Supercontinuum Sources.

Module II

Laser Fundamentals, Gas Lasers, Solid State Lasers, Semiconductor Laser Diodes, Safety Standards and Hazard Classifications, Laser Applications.

Module III

Detector Characteristics Quantum Efficiency, Response Time, Spectral Response. Types of Photoeffects-Photovoltaic Effect, Photoemissive Effect, and Photoconductive effect. Optical Detectors - UV, VIS, NIR, & IR Ranges.

Module IV

Types of Photon Detectors: Photodiodes, Photomultiplier Tube (PMT), Photodiode Array (PDA), Light Dependent Resistor (LDR), Charge-Coupled Device (CCD), Time Gated Detectors-Intensified Charged Coupled Device (ICCD).

Text Books:

1. Introduction to Solid-State Lighting - Zukauskas, Shur, Gaska, Wiley (2002)
2. Laser Fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
3. E. L. Dereniak, and D. G. Crowe, Optical Radiation Detectors, (Wiley Series in Pure and Applied Optics), Wiley, New York (1984).

References

1. Kingston, Robert H., Detection of Optical and Infrared Radiation, (Springer Series in Optical Sciences, Vol.10), Springer Verlag, New York (1978).
2. Chandra Roychoudhuri (Editor), Fundamentals of Photonics, SPIE (2008)
3. Bahaa E. A. Saleh Malvin Carl Teich, Fundamentals of Photonics, John Wiley & Sons, Inc. (1991)

24: Measurements and Optical Instrumentation

Course Code: 24
Credits: 4
Hours : 60 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 detectors and 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, spectrophotometers, calorimeters Spectrometer Design.

Text Books:

1. Measurement, Instrumentation and experiment design in Physics and Engineering Michael Sayer and Abhai Mansingh prentice-Hall India.
2. J.Wilson & J F B Hawkes, Opto Electronics: An Introduction, Prentice Hall of India, (2011), 3rd ed.
3. Rajpal, S.Sirohi , Wave Optics and its Application, (2001), 1st ed.
4. A Yariv , Optical Electronics/C.B.S. Collage Publishing, New York, (1985).
5. Pollock ,Fundamentals of OPTOELECTRONICS, (1994).

25: Modern Optics

Course Code: 25
Credits: 4
Hours : 60

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 Fraunhaufer diffraction - Zone plate – Applications of the Fourier transform to diffraction – Apodization and spatial filtering - Holography - Recording and reconstruction of wave fronts.

Module IV

Nonlinear Optics - Polarization response of materials to light – Nonlinear Wave equation – Optical rectification – second Harmonic Generation – Phase matching – Sum and difference Frequency generation – Third harmonic generation – Intensity dependent refractive index - self focusing - B integral – Optical Parametric oscillator –Two photon absorption.

Text Books:

1. G. R. Fowles, Introduction to modern optics 2nd Ed., Dover Publications (1975).
2. E Hecht and A R Ganesan, Optics 4th Ed., Pearson (2008).
3. Fibre optics and Optoelectronics, R.P. Khare, Oxford University Press, (2004).
4. W T Silfvast, Laser Fundamentals 2nd Ed., Cambridge University Press
5. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press, 2003.

Reference Books:

1. M. Born and E. Wolf, Principles of Optics 7 th Edition, Cambridge University Physics (2013).
2. Bahaa E . A. Saleh and Malvin Carl Teich , Fundamentals of Photonics 2 nd Ed., Wiley.
3. Optoelectronics: An Introduction, J. Wilson and J.F.B. Hawkes, PHI, (2000).

26: Molecular Physics and Laser Spectroscopy

Course Code: 26
Credits: 4
Hours : 60

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 in Valence 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 a spectroscopic 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 rotational spectra. Nuclear Quadrupole hyperfine interaction due to single nuclear spin. Zeeman effect in rotational spectra. Description of microwave spectrometer.

Module III

Electronic spectra of diatomic molecules – Rotational Structure of electronic bands – PQR branches – Bandhead formation and shading – Combination relations for evaluation of rotational constants.
Laser systems – three and four level schemes – solution of rate equations for three level systems – System description of semiconductor diode lasers – Ti-sapphire lasers and Tunable Dye Lasers.

Module IV

Description of diode laser spectrometer – examples of diode laser spectra of diatomic molecules. Dunham representation of re-vibrational transitions. (basic ideas only)
CW dye laser spectrometers - basic ideas of intermodulated fluorescence spectroscopy – Microwave frequency - optical double resonance spectroscopy and infrared optical double resonance spectroscopy

Text Books:

1. R.K. Prasad, Quantum Chemistry, NEW AGE; Fourth edition (2010)
2. W. Gordy and E.L. Cook, Microwave Spectroscopy, John Wiley & Sons (1984)
3. G. Herzbera, Spectra of Diatomic Molecules, Van Nostrand Reinhold Company (1979)

Reference Books:

1. Qrazio Svelto, Principles of Lasers
2. Eizi Hirota, High Resolution Spectroscopy of Transient Molecules
3. A. Mooradian.T., Jaeger and P. Stockseth, Tunable Lasers and Applications
4. A.B. Budgor, L. Esterowitz and L.G. Deshazer, Tunable Solid State Lasers-II

27: Nondestructive Measurement Techniques and Applications

Course Code: 27
Credits: 4
Hours : 60

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 allied 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 measurements.

Module III

Ultrasonic Testing - Basic properties of Sound Beam - Sound waves - Velocity of ultrasonic waves - Acoustic pressure - Behaviour of ultrasonic waves - Ultrasonic Transducers - Characteristics of ultrasonic beam - Attenuation - Inspection methods - Normal incident pulse-echo inspection - Normal incident through transmission testing - Angle beam pulse-echo testing -Criteria for probe selection - Flaw sensitivity - Beam divergence - Penetration and resolution - Techniques for Normal beam inspection - Fatigue cracks -Inclusions, slag, porosity, and large grain structure - Thickness measurement-corrosion detection - Intergranular cracks-hydrogen attack-Techniques for Angle beam inspection- Flow characterization techniques - Ultrasonic flaw detection equipment - Modes of display - A-scan - B-scan - C-scan - Immersion testing - Applications of ultrasonic testing -Advantages - Limitations - Standards.

Module IV

Visual Examination Basic Principle - The Eye - Defects which can be detected by unaided visual inspection-Optical Aids Used for Visual Inspection-Microscope Borescope - Endoscope - Flexible fibre-optic Borescope (Flexiscope) - Telescope
The concept of Holographic imaging - The inline hologram- The off axis hologram-Fourier hologram-Nondestructive 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 spectroscopy as nondestructive tool. Instrumentation.

Text books

1. Practical Nondestructive Testing, Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Publishing House New Delhi
2. Optical Holography-Principles techniques and applications, P.Hariharan, Cambridge Studies in Modern Optics

Reference Books :

1. Electrical and Magnetic Methods of Non -Destructive Testing, Jack Blitz,Champan & Hall,2-6 Boundary 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

28: Non-equilibrium Statistical Physics

Course Code: 28
Credits: 4
Hours : 60

Course Objectives

1. To introduce the important concepts of 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. Differentiate non-equilibrium systems from equilibrium systems wherever applicable.
4. Apply large deviation theory in physical systems.
5. Understand the technical terminology, and to follow the scientific literature of past and recent advances in the field.

Module I

Introduction to stochastic processes: basics of probability theory, Random numbers, Probability distributions, Moments, cumulants, generating functions Central limit theorem, Levy stable distributions.

Module II

Brownian motion, first passage properties, Markov processes, Master equation, Detailed balance condition, Langevin equations and Fokker-plank equation, Solutions to the Fokker plank equation for simple systems.

Module III

Correlations, response, Fluctuation dissipation theorem, Linear response theory, Large deviation theory, Fluctuation relations.

Module IV

Non-equilibrium phenomena, Nucleation, Spinodal decomposition, Active and driven systems, Glassy systems, granular matter Exactly solvable systems.

Text Books :

1. N G Van Kampen, Stochastic Processes in Physics and Chemistry (North-Holland Personal Library) North Holland; 3rd edition.
2. V Balakrishnan, Elements of Nonequilibrium statistical mechanics, Ane books, Delhi & CRC Press (2008)
3. R. Kubo, M Toda, N. Hashitsume, Statistical Physics II:Non-equilibrium statistical Mechanics, Springer-verlag, Berlin (1985)
4. A Kinetic view of statistical physics: Pavel L. Krapivsky, Sydney Redner, Eli Ben-Naim Cambridge University Press, (2013)

Reference Books :

1. Non-equilibrium Statistical Mechanics, Robert Zwanzig, OUP USA (2001)
2. Non-equilibrium Statistical Physics: Linear Irreversible Processes, Noelle Pottier OUP (Oxford Graduate Texts)
3. The mechanics and statistics of Active matter, Sriram Ramaswamy, Annual Review of Condensed Matter Physics 323-345 (2010).

29: Non-linear Dynamics and Chaos

Course Code: 29
Credits: 4
Hours : 60 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 in systems.

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)

30: Non-linear Optics

Course Code: 30
Credits: 4
Hours : 60

Course Objective

Acquire 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. Bloch equations – self induced transparency.

Module IV

Fibre optics – normal modes of optical fibres – nonlinear Schrödinger equations – linear theory.
Basic concepts of solitons and non-linear periodic structures. Effect of fibre loss – effect of wave guide property of a fibre – conditions of generation of a solitons in optical fibres.

Text Books:

1. D.L. Mills, Nonlinear Optics, Springer, 2nd,ed. (1998)

Reference Books:

1. F.Zernike and J.E. Midwinter, Applied Nonlinear Optics
2. G.C. Badwin, Nonlinear Optics
3. A. Hasegawa, Optical Solitons in Fibres

31: Phase Transition and Critical Phenomena

Course Code: 31
Credits: 4
Hours : 60

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 degrees of 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).

32: Physics of Nanomaterials

Course Code: 32
Credits: 4
Hours : 60

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 nanomaterials.

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 magnetoresistance (CMR).

Module III

Synthesis of nanostructured materials, Bottom-up and Top-down processes, method of making 1- D and 2-D nanomaterials, high energy ball milling, co-precipitation technique, sol gel synthesis, solvothermal methods-control of grain size chemical vapor deposition (CVD), physical vapor deposition (PVD), Lithography.

Module IV

Characterization of nanomaterials, preliminary ideas about the operation and characterization of nano materials using scanning electron microscope (SEM), transmission electron microscope (TEM), scanning tunneling microscope (STM), atomic force microscope (AFM) and x-ray diffraction (XRD).

Text Books:

1. Michael F. Ashby, Paulo J. Ferreira, Daniel L. Schodek, Nanomaterials, Nanotechnologies and design, an introduction for engineers and architects, Elsevier (2009).

2. 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-science publication (1993)

3. A I Gusev and A A Remphal, Nanocrystalline materials, Cambridge International Science Publishing

4. Hari Singh Nalwla, Nanostructured materials and nanotechnology Vol. I, II, III, IV, V, VI, VII,VIII, IX (2002)

5. K L Chopra and Inderjeet Kaur, Thin Film Device Applications, Plennum Press (1983)

6. J H Davis, Physics of low dimensional structures Cambridge (1998).

33: Principles of Biomedical Instruments

Course Code: 33
Credits: 4
Hours : 60

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

X-rays:Principle and production of X-rays, Interaction of X rays with matters, Transfer characteristics of screen, Film and image intensifier systems, Properties of X-ray films and screens, Characteristics of Imaging system by image modulation transfer functions, Radiography:Various components of Radiography systems – Exposure switching and control of exposure time – Types of timer circuits, Filament circuit and KV– mA controls – HT units – X-ray tubes for various medical applications – fixed anode, rotating anode, X-ray tubes for specialized applications – collimators

Module III

Medical ultrasound: Physics of ultrasonic waves, Interactions with body matter, Generation and detection, Single element transducer, Linear and sector scanning Transducer arrays, Different modes of display, Modes of transmission of ultrasound, Colour Doppler, Ultrasonic diagnosis in abdomen, Breast, Heart, Chest, Eye, Kidney, Skull, Pulsatile motion, Pregnant and Non-Pregnant uterus. Ultrasound pulse echo imaging system, Design of scan converters, Design of frame grabbers, 2D scanners.

Module IV

Magnetic Resonance Imaging:Principles of image formation– MRI instrumentation-magnets Gradient system – RF coils receiver system, Pulse sequence– Image acquisition and reconstruction techniques, Application of MRI, Fundamentals of magnetocardiography and magnetoencephalography

Text Books:

Text Books :

1. Fundamental Physics of radiology,W.J. Meredith & J.B. Massey, Varghese Publishing House, Bombay, 1992.
2. The Physics of Diagnostic Ultrasound, Peter Fish, John Wiley & Sons, England, 1990. 4.
3. Ultrasound Physics & Instrumentation,D.L. Hykes, W.R. Hedrick & D.E. Starchman, Churchill Livingstone, Melbourne, 1985.

Reference Books :

1. Principles of Applied Biomedical Instrumentation,L.A.Geddes & L.E.Baker, Wiley
2. Handbook of Analytical Instruments, Khandpur R S, Tata McGraw Hill,1989
   India Pvt.Ltd, Third Edition, 1989.
3. Radiographic Imaging,D.N. & M.O. Chesney, CBS Publishers, 1990.
4. The Physics of Medical Imaging, S. Webb, IOP Publishing Ltd., 1988.

34: Quantum Field Theory

Course Code: 34
Credits: 4
Hours : 60

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 Feynmann 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-- canonical quantization of Dirac fields-Feynman propagator.
(Sect. 4.4-4.5, 5.1-5.4 of Ref. 1)

Module III

Canonical quantization of Maxwell's field-Maxwell's equations-Lorentz and Coulomb gauges-Lagrangian density.
Canonical quantization in Lorentz and Coulomb gauges-Coulomb interaction and transverse delta functions.
(Sect. 6.1--6.2, 7.1--7.5, 7.7 of Ref. 1)

Module IV

Interacting fields, interaction picture, time evolution operator, scattering matrix, Wick's theorem(no proof), Feynman rules(no rigorous treatment) -Moller and Compton scattering.
(Sect. 8.1-8.7 of Ref. 1)
Spontaneous symmetry breaking, scalar theory, Goldstone theorem(no proof), spontaneous breaking of gauge symmetries.
(Sect. 8.1-8.3 of Ref. 2)

Text Books:

1. Field Quantization, Greiner W and Reinhardt J, Springer, (2013)
2. Quantum Field Theory, Ryder L H, Cambridge University Press; 2 edition (1996)

Reference Books:

1. Quantum Field Theory, Itzykson C and Zuber J B, Dover Publications Inc., (2006)
2. Relativistic Quantum Fields I & II, Bjorken J D and Drell S D, McGraw Hills(1965)

35: Quantum Computation and Information

Course Code: 35
Credits: 4
Hours : 60

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 techniques involved 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 entropy - 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)

36: Quantum Optics

Course Code: 36
Credits: 4
Hours : 60

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 quantization, 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 susceptibilities.

Module II

Atom-field interaction for two level atoms – blackbody radiation – Rabi Flopping.
Introduction to laser theory – the laser self consistency equation – steady state amplitude and frequency – stability analysis – mode pulling.

Module III

Doppler – broadened lasers – Two mode operation and the ring laser – mode locking – single mode semiconductor theory – evaluation of laser gain and index formulas – transverse vibrations and Gaussian beams.
Field quantization - single mode field quantization – multimode field quantization – single mode in thermal equilibrium. Coherent states – coherence of Quantum fields p ( ) representations.

Module IV

Interaction between atoms and quantized fields – Dressed states – Jaynes-Cummings model – collapse and revival.
Squeezed state of light – squeezing the coherent states – two side mode master equation – two mode squeezing – squeezed vacuum.

Text Books:

1. P. Meystre and M. Sargent III, Elements of Quantum Optics (2^{nd} 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

37: Semiconducting Materials and Devices

Course Code: 37
Credits: 4
Hours : 60

Course Objectives

To teach the basics of Semiconducting materials and their applications.

Course Outcomes

At the end of the course, the student will be able to:

1. Understanding of the basic and advanced properties of semiconductor materials.
2. The importance of semiconductor materials in various device applications.
3. Working of bipolar junction transistors and field effect transistors on a semiconductor perspective.
4. Principle and working of optoelectronic devices such as solar cells, photodetectors, light emitting diodes etc.

Module I

Carrier Drift - Drift Current Density - Mobility Effects - Conductivity Velocity Saturation- Carrier Diffusion - Diffusion Current Density - Total Current Density Graded Impurity Distribution - Induced Electric Field - The Einstein Relation. Reciprocal Lattice - Bragg Reflection of Electron Waves - Brillouin Zones - Important Features of Energy Bands of Si, Ge, and GaAs (derivation not included).

Module II

Intrinsic, Extrinsic, and Compound Semiconductors - Electrons and Holes - Semiconductor Statistics - Electron and Hole Mobilities and Drift Velocities - Hall Effect - Magneto resistance - Quasi Fermi Levels - Generation and Recombination of Carriers. p-n Junction under Zero Bias Condition - Depletion Capacitance - Diffusion Capacitance - Tunneling and Tunnel Diodes - Junction Breakdown - Schottky Barriers Ohmic Contacts.

Module III

Bipolar Junction Transistor: Principles of Operation - Doping Profile Electron Diffusion Current in the Base - BJT as a Switch - Bipolar Transistors in Integrated Circuits. FET: Basic Principles - Surface Charge in Metal Oxide Semiconductor Capacitors - MOSFET: Principles of Operation Charge Coupled Devices - Advanced MOS Devices

Module IV

Crystalline Solar Cells Conversion Efficiency - p-n Junction Solar Cells - Spectral Response Equivalent Circuit Amorphous Silicon Solar Cells Photo Detectors - PIN Diode Detectors - Electroluminescence of Electromagnetic Waves in Two-Level Systems LEDs - Semiconductor Lasers: Optical Gain - Integrated Optoelectronics.

Text Books:

1. Michael Shur, Physics of Semiconductor Devices, Prentice Hall of India, 1995.
2. Donald A. Neaman, Semiconductor Physics, and Devices, Tata McGraw Hill.
3. Sze S. M., Physics of Semiconductor Devices, John Wiley & Sons, 1993.

Reference Books:

1. S. S. Islam, Semiconductor Physics and Devices, Oxford University Press.
2. Karl Hess, Advanced Theory of Semiconductor Devices, Prentice Hall of India.
3. Jasprit Singh, Semiconductor Devices: An Introduction, McGraw Hill, 1994.

38: Solar Photovoltaic Technology

Course Code: 38
Credits: 4
Hours : 60

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 technologies 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 - Integrating Renewable Energy - Renewable energy scenarios - Economic Analysis of Renewable Energy System - Photovoltaics - history of photovoltaics - status of Photovoltaics - Grid Parity - Challenges - trends in photovoltaic technology - Policy Impacts - PV market growth scenarios - Solar radiation: Solar constant - Solar Spectra - Air Mass - Global radiation -Position of the Sun - Solar Insolation Physics of Solar cells: Fundamental Properties of Semiconductors - Band model - Doping - Semiconductor types - absorption of light - recombination - p-n junction - Solar cells - Solar cell parameters - Spectral response - Upper limits of cell parameters - Thermodynamic limit-the Schokley-Quiesser limit - effect of temperature - effect of parasitic resistances

Module II

Solar PV technologies (qualitative)
First generation: Silicon wafer based technology: Design of c-Si solar cell - loss mechanism - 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 purification, navigation, solar cars, defense, etc.

Text Books:

1. S.R. Wenham, M. Green, M.E. Watt, R. Corkish, A. Sproul, Applied Photovoltaics ? 2nd Edition (2009)
2. K. Mertens, Photovoltaics: Fundamentals, Technology and Practice, John Wiley & Sons Ltd (2014)
3. Smets, K. Jager, O. Isabella, R. V. Swaaij, M. Zeman, Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems, UIT Cambridge Ltd. (2016).

Reference Books:

1. Handbook of Photovoltaic Science and Engineering - 2nd Ed. , A. Luque, S. Hegedus (editors), John Wiley & Sons Ltd (2011)
2. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and applications, 3rd Edition, PHI Learning Pvt. Ltd. (2019).
3. Jenny Nelson, The Physics of Solar Cells, Imperial College Press (2003).
4. Godrfrey Boyle (Eds), Renewable Energy: Power for a sustainable future, Oxford University Pres (2012).
5. S.P. Sukhatme, J.K. Nayak, Solar Energy 4th Edn, McGraw-Hill Education (2017)
6. SM Sze and Kwok K Ng, Physics of semiconductor devices, third edition ,John Wiley & Sons (2007)
7. R.F. Pierret, Semiconductor Device Fundamentals
8. D. A. Neamen and D. Biswas ,Semiconductor Physics and Devices

39: Sophisticated Material Characterization Techniques

Course Code: 39
Credits: 4
Hours : 60

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

X-ray diffraction - X-ray methods - Production of X-rays and X-ray Spectroscopy - Instrumental units - Detectors for the measurements of radiation - Semiconductor detectors - Direct X-ray methods - Powder method - rotating crystal method - specimen preparation - -Single crystal diffractometer – Electron diffraction-Neutron diffraction- Reflection high energy electron diffraction (RHEED), XPS-principle-Instrumentation and applications-X-ray topography(XRT)- Rutherford Back Scattering analysis(RBS)- XRF (X-ray fluorescence)- Synchrotron radiation- Applications (Qualitative) – XANES-XAFS.

Module II

Morphological studies Optical microscope, Electron matter interaction- Fundamental principle and instrumentation and applications of Scanning Electron Microscope (SEM)- Transmission Electron Microscope (TEM) - Scanning transmission electron microscopy (STEM)- Atomic Force Microscope- Elemental composition analysis-EDX-EELS- Auger electron spectroscopy (AES)- Optical measurements-UV-visible spectroscopy- Determination of band gap of semiconductors- Atomic emission spectrometry.

Module III

Absorption and Emission spectroscopy - Nature of electromagnetic radiation - Atomic energy level-Raman effect - Raman Spectroscopy- Instrumentation -Infrared spectroscopy - Near IR - Mid IR - Far IR Region - Correlation of infrared spectra with molecular structure - structural Analysis - Radiation sources - Detectors - Thermal Detectors -Spectrophotometers - Fourier Transform Interferometer Quantitative analysis- Sample handling. - Luminescence –Photoluminescence(PL) spectroscopy–Nuclear magnetic Resonance Spectroscopy - Basic principles - Quantitative analysis-Dyanamic Light scattering- Secondary ion mass spectroscopy (SIMS).

Module IV

Thermal analysis - Differential Thermal Analysis - Instrumentation – Differential Scanning calorimetry - Thermogravimetry - Instrumentation - Methodology of Differential Scanning Calorimetry and

Thermo Gravimetric Analysis - Conductance method – Electrical conductivity- Measurement of electrical conductance - Measurement of dielectric constant- Hall Mobility – Magnetic measurements-SQUID magnetometer- Fundamentals of cyclic voltammetry CV measurements.

Text Books:

1. B.D. Cullity, Element of X-ray Diffraction, Addison Wesley Publication, 1978.
2. X.F. Zong, Y.Y.Wang, J. Chen, Material and Process characterization for VLSI, World Scientific, New Jersey, 1988.
3. H.H.Willard, D.L.Merrti, Dean and Settle, Instrumental methods of analysis, CBS publishers.1992.
4. Yang Leng, Materials Characterization Introduction to Microscopic and Spectroscopic Methods; Wiley-VCH-Second Edition.
5. P.E. J. Flewitt and R K Wild Physical methods for Materials Characterization, IOP Publishing (2003).
6. P.Duke ; Synchratron radiation, Oxford university press 2000.
7. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
8. Zoski, C. G., Ed. Handbook of Electrochemistry; Elsevier: Amsterdam, The Netherlands, 2006.
9. John Clarke , Alex I. Braginski; The SQUID Handbook: Fundamentals and Technology of SQUIDs and SQUID Systems- Wiley-VCH.
10. Banwell and E M McCash, Fundamentals of Molecular Spectroscopy; McGraw-Hill Education (India) Pvt Limited, 2001.

40: Statistical Techniques in Physics: with Python Applications

Course Code: 40
Credits: 4
Hours : 60

Course Objectives

The course aims to provide a broad introductory overview of various statistical methods and techniques used in Physics with applications in astronomy, cosmology, nuclear/high-energy Physics, biophysics, etc. Introduce time series and regression methods and Machine Learning.

Course Outcomes

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

1. Learn the most commonly used probability distributions with their applications in Physics
2. Understand and apply techniques used for statistical inference via model fitting and parameter estimation.
3. Learn and apply advanced topics of Bayesian inference and Monte Carlo methods.
4. Learn and apply modern techniques like time series analysis and machine learning.

Module I

Elements of probability theory: conditional probability, Bayes theorem. Random variables: continuous and discrete case, probability distribution functions, functions of random variables and expectation values, error propagation, Limit theorem
Common probability distributions and their applications in Physics: Low of large numbers; binomial, Poisson, Gaussian,log-normal, power law distributions etc.; Multivariate distributions - multivariate Gaussian.

Module II

Statistical inference: General Concepts - population, sample, statistic, estimator, bias and MSE, sampling distribution - chi2, Student-t distributions
Hypothesis testing: Null and alternate hypothesis, test statistic, significance level, p-value
Point estimation - method of moments, maximum likelihood method, least square and Chi-square fitting, Confidence intervals and limits - the goodness of fit.

Module III

Bayesian inference and their applications in Physics - Bayesian parameter estimation.
Stochastic Processes in Physics: Continuous Processes - White noise and other examples, Point Processes - Poisson Process, Spatial Point processes, correlation functions, Markov Process.
Monte Carlo Methods - Uniformly distributed random numbers, The acceptance-rejection method, Applications, Markov Chain Monte Carlo methods - The Metropolis-Hastings Algorithm.

Module IV

Time series analysis in Physics - basic concepts, auto, and cross-correlations; Regression analysis - least square linear regression, non-linear regression.
Introduction to Machine Learning: Elements of neural networks, Applications

Text Books:

1. Probability and Statistics: The Science of Uncertainty (Second Edition), Michael J. Evans and Jeffrey S. Rosenthal, W. H. Freeman Publishers, 201

2. Statistical data analysis (second edition), Glen Cowan, Oxford University Press Inc. Newyork 2012

3. Introduction to statistics and data analysis for physicists (3rd edition), Gerhard Bohm, Günter Zech, Verlag Deutsches Elektronen-Synchrotron, 2017

4. Statistical methods in experimental Physics (second edition), Frederick James, World Scientific Publishing, 2006

5. Modern Statistical Methods for Astronomy: With R Applications, E. D. Feigelson & G. J. Babu, Cambridge University Press, 2012

6. Stochastic Processes in Physics and Chemistry (third edition), N. G. Van Kampen, Elsevier Science B, 2007

7. Introduction to Probability, Statistics, and Random Processes, Hossein Pishro-Nik, https://www.probabilitycou

41: Thin film physics

Course Code: 41
Credits: 4
Hours : 60

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 in day 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 - Evaporation mechanisms - Directionality of evaporating molecules - vapour sources - wire and metal foils - Electron beam gun- sputtering - Glow discharge sputtering - Bias sputtering - Reactive sputtering - Magnetron sputtering - Ion beam sputtering - PLD- epitaxial films- MBE Chemical Vapour deposition: conventional CVD, Plasma enhance CVD, MOCVD, Atomic layer Deposition Film thickness measurements: Optical methods - basics of multilayer modelling- Ellipsometry -Other techniques: Electrical - Mechanical - Micro-balance - Quarts crystal monitor - X ray reflectivity.

Module III

Nucleation Theories: Condensation process - Theories of Nucleation – Capillarity theory – Atomistic theory – Comparison – stages of film growth – Incorporation of defects during growth.
Optical properties:Reflection and transmission at an interface – Reflection and transmission by a single film – Optical constants - Refractive index measurement techniques – Reflectivity variation with thickness Patterned films: lithography techniques – film etching methods.

Module IV

Electrical Properties: Electrical Properties: Sources of resistivity – sheet resistance – electron mobility- Hall Effect -TCR – Influence of thickness on resistance – Theories of size effect – Theories of conduction in discontinuous films – Electronic conduction in thin insulating films- MIS structure -Dielectric properties – D.C. conduction mechanisms – High and low field conduction – Temperature dependence – space charge limited conduction – A.C. conduction mechanisms Application of thin films: electrodes, transparent conducting oxides, thin film devices: LED, TFT, -Solar cells - optical and decorative coatings - dichroic coatings- biomedical coatings – tribological coatings.

Text Books:

1. Hand Book of Thin Film Technology, Maissel and Glang, McGraw Hill Higher Education (1970)
2. Materials science of thin films deposition and structures, Milton Ohring, Academic press, 2006.
3. Vacuum deposition of thin films, L. Holland, Chapman and Hall.
4. Glow discharge processes, B. Chapman, Wiley, New York.
5. Physics of Non-Metallic Thin Films, Dupy and Kachard, Plenum Press (1976).
6. Scientific Foundations of Vacuum Technology, S. Dushman and J.M. Lafferty, John Wiley & Sons, Inc.; 2nd Ed. (1962).
7. Thin Film Phenomena, K.L. Choppra, McGraw-Hill Inc.,US (1969).

Reference Books:

1. O. S. Heavens, Optical Properties of Thin Films, by, Dover Publications, Newyork 1991
2. Donald L. Smith ‘Thin Film deposition principle and Practice’s, McGraw Hill international Edition, 1995.
3. Various web resources and research papers

Skill Enhancement Courses

42: Science Communication

Course Code: 42
Credits: 3
Hours : 45 hours

Course Objective

This course intends to develop communication and data presentation skills (oral, written, and presentation) of the students which will enable them to present scientific ideas clearly and concisely whether in an interview or in a scientific paper or presentation. The course explores various aspects of science communication, including communicating science to the general public, media, policymakers, and other scientists. Students will learn about different communication strategies, techniques, and tools to effectively communicate complex scientific information to a broad audience. The course will be mostly activity based.

Course Outcome

1. Present data and results of an experiment accurately and effectively.
2. Understand the importance of effective science communication.
3. Identify different target audiences and tailor communication strategies to meet their needs.
4. Develop skills in writing for diverse audiences and purposes.
5. Develop skills in oral presentation and public speaking.
6. Understand the ethical considerations in science communication

Module I (Weeks 1-5)

Good lab practices, Quantifying error in experiments and data analysis, Error propagation, Obtaining good statistical accuracy, Central Limit theorem.
Publishing scientific results: The structure of a scientific paper and presentation. Academic ethics & Intellectual property rights.

Module II (Weeks 6 - 12)

Week 6 - 7: Writing for diverse audiences and purposes, Writing for the web and social media.
Activity: Developing concise science writing skills: Students have to prepare an article for the common man explaining a given scientific research paper/topic to the public.
Week 8 - 10: Preparing and delivering effective speeches, Engaging with the audience.
Activity: Students have to prepare and record a 5-10 min podcast explaining a scientific idea to the public.
Week 11-12: Handling questions and interviews
Activity: Each student takes turns attending a 10 min interview with other students on selected topics.

Module III (Weeks 13 - 16)

Week 14-16: Preparing and delivering effective presentations, Using visual aids to communicate science, Principles of data visualization.
Activity: Students have to prepare a 10 min PowerPoint presentation on a given topic.
Week 17-18: Final Project: Prepare a scientific report on an experiment the students performed in the lab with abstract, introduction, content, results and references.

Text Books:

1. Science Communication - A Practical Guide for Scientists, L. Bowater, K. Yeoman, Wiley

2. John Durant, and Bina Venkataraman. STS.034 Science Communication: A Practical Guide. Fall 2011. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu. License: Creative Commons BY-NC-SA.

3. Effective science communication, S.Illingworth and S. Allen, IOP.

4. The Scientist's Guide to Writing: How to Write More Easily and Effectively throughout Your Scientific Career by Stephen B. Heard

5. Communicating Science: A Practical Guide by Gavin Bremner and Alan S. J. King

43: Basic Instrumentation Skills

Course Code: 43
Credits: 3
Hours : 45 hours

Course Objective

This course is to get exposure with various aspects of electronic instruments and their usage.

Course Outcome

After completion of this course the students will be able to

1. Understand the concepts behind the operation of voltmeters. They will be able to use it for different applications.

2. Understand the concepts behind the operation of oscilloscopes and signal generators. They will be able to use it for different applications.

3. Understand the basics behind the working of impedance bridges and digital multimeter. They will be able to use it for different applications.

Module I Basic of Measurement, Electronic Voltmeter and Oscilloscope: Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements. Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance. Principles of voltage measurement (block diagram only). Specifications of an electronic Voltmeter/ Multimeter and their significance. Type of AC millivoltmeters. Block diagram of ac millivoltmeter, specifications and their significance.

Module II Oscilloscopes and signal generators: Block diagram of basic CRO. Specifications of CRO and their significance. Use of CRO for the measurement of voltage (dc and ac), frequency and time period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: principle of working. Block diagram, explanation and specifications of low frequency signal generator and pulse generator. Brief idea for testing, specifications. Distortion factor meter, wave analysis.

Module III Impedance Bridges and digital instruments: Block diagram of bridge. working principles of basic (balancing type) RLC bridge. Specifications of RLC bridge. Block diagram and working principles of a Q- Meter. Digital LCR bridges. Comparison of analog & digital instruments. Characteristics of a digital meter. Working principles of digital voltmeter. Block diagram and working of a digital multimeter. Working principle of time interval, frequency and period measurement using universal counter/ frequency counter, time- base stability, accuracy and resolution.

Text Books:

1. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.

2. Logic circuit design, Shimon P. Vingron, 2012, Springer.

3. A text book in Electrical Technology - B L Theraja - S Chand and Co.

4. Performance and design of AC machines - M G Say ELBS Edn.
5. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
6. Electronic Devices and circuits, S. Salivahanan & N. S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill

44: Thin Film Growth, Characterization and Measurements Technology

Course Code: 44
Credits: 3
Hours : 45 hours

Course Objective

This course aims for skill enhancement of students in thin film technology and measurements. This course provides an introduction to thin films materials, applications and characterization techniques. The course will also provide them with basics of electrical characterization techniques of thin films and devices.

Course Outcome

1. Understand various thin-film deposition techniques-PVD, CVD and microstructuring.
2. Understand various thin-film characterization techniques.
3. Understand various measurement devices and types of equipment.
4. Design electronics circuit and interface with computer.

Module I Thin-Film Deposition Techniques - PVD-Introduction to thin-film deposition techniques Physical Vapor Deposition (PVD) methods: evaporation, sputtering, PLD, e-beam evaporation. CVD techniques and microfabrication techniques.

Module II Thin-Film Characterization Techniques: scanning probe microscopy, spectroscopy, and ellipsometry Surface analysis techniques: X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES). Thin-film thickness measurement methods: interferometry, profilometry, and quartz crystal microbalance, STM, Atomic force microscopy, SEM, TEM basics.

Module III Measurement Devices and Equipment Introduction to various measurement devices and their principles of operation Instrumentation amplifiers, Sensors and transducers: temperature, pressure, flow, and level sensors Data acquisition systems and Python/LabVIEW programming, Microcontroller programming and interfacing Designing circuits to interface with computers and data acquisition systems, Measurement emphasis on 2 probe, 4-probe, Van der Pauw geometry, hall geometry. Measurement using DC technique current source and voltmeter, AC technique Lock-in basics, low temperature electrical characterization and magnetotransport measurements.

Text Books:

1. Thin Film Deposition: Principles and Practice, Donald L. Smith, McGraw Hill Education (1995).
2. Principles of Materials Characterization and Metrology , Kannan M. Krishnan, Oxford University Press (Spring 2021).
3. Handbook of Thin-Film Deposition Processes and Techniques edited by Krishna Seshan.
4. The material science of thin films, Milton Ohring, Academic Press 1992.

Reference Books:

1. The Art of Electronics by Paul Horowitz and Winfield Hill, Cambridge University Press 3rd edition.
2. Op-Amps and Linear Integrated Circuits,Ramakant A. Gayakwad, Fourth Edition, Pearson.
3. Microcontrollers Theory and applications, Ajay Deshmukh.

45: Vacuum Technology and Workshop Practices

Course Code: 45
Credits: 3
Hours : 45 hours

Course Objective

This course aims for skill enhancement of students in vacuum technology and mechanical designs. This course provides an introduction to the principles and applications of vacuum technology. It covers the fundamental concepts, techniques, and equipment used in creating and maintaining vacuum environments. The course will provide them with basics of mechanical design and introduce them to mechanical workshop practices.

Course Outcome

1. Understand and have hands-on experience with vacuum pumps, chambers, and gauges from Low vacuum to Ultra high vacuum

2. Design mechanical parts using CAD software.

3. Manufacturing mechanical parts with 3D printing and various machining process.

Module I Introduction to Vacuum Technology-Basics of vacuum, its applications, and importance Vacuum pressure measurement techniques and gauges-Introduction to vacuum pumps: types, working principles, and applications. Low Vacuum Systems Introduction to low vacuum systems Design and operation of rotary vane pumps Vacuum chamber design and construction Leak detection and prevention techniques High Vacuum Systems Introduction to high vacuum systems Operation and maintenance of diffusion pumps and turbomolecular pumps Ultra-high vacuum (UHV) systems and components UHV gauges and pressure measurement techniques.

Module II Mechanical Design using CAD Software- Introduction to Computer-Aided Design (CAD) Software- 2D and 3D modeling techniques-Parametric design and assembly modeling Design optimization and simulation tools. Manufacturing Techniques - 3D Printing Introduction to 3D printing technologies Types of 3D Printers and their applications Design Considerations for 3D Printing Post-processing and finishing techniques for 3D-printed parts, Manufacturing Techniques - Machining Processes Introduction to various machining processes: milling, turning, drilling, etc.CNC machining and programming.

Module III Workshop practice: Machining tool selection and cutting parameters Surface finishing and quality control in machining processes Use of lathe, milling machine, drilling machine, welding machine and elementary carpentry. Working with metals such as brass, aluminum, and steel. CAD drawing-stl conversion-3d printing

Text Books:

1. Vacuum Technology, A. Roth, North Holand, Third Edition, 1990.

2. FreeCAD: Learn Easily & Quickly Paperback by V. K. CHAUDHARY.

3. 3D Modeling and Printing With Tinkercad: Create and Print Your Own 3D Models 1st Edition, James Floyd Kelly.

4. Machining Fundamentals, 11th Edition, Bob Dixon and John R. Walker, G-W publisher.

5. A Textbook of Workshop Technology, RS Khurmi, JK Gupta, S. Chand Publishing, 2008.

Reference Books:

1. Engineering Design with SolidWorks by David C. Planchard and Marie P. Planchard

2. 3D Modeling with Tinkercad for 3D Printing, Toysinbox 3D Printing

3. Handbook of Vacuum Technology, Karl Jousten, John Wiley & Sons, 2008

4. Ultrahigh Vacuum Practice, 1st Edition G. F. Weston, Butterworths

DEPARTMENT OF STATISTICS

Scheme of Examinations and Syllabus for
the Five Year Integrated M.Sc. Degree Programs in
Mathematics/Physics/Chemistry/Biological Sciences

(2023 Admission Onwards)

Interdepartmental Core/Elective Courses in Statistics

DEPARTMENT OF STATISTICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Scheme

Semester I

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
STAT 10101	Introductory Statistics	MDC/IDC	3-1-0	50	50	100	3

Semester II

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
STAT 10201	Probability Distributions	MDC/IDC	3-1-0	50	50	100	3

Semester III

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. eval.	End Sem	Total	Credit
STAT 10301	Statistical Methods	MDC/IDC	3-1-0	50	50	100	3

Semester IV

Course Code	Course Name	Course Type	L-T-P	Marks Distribution			
				Cont. Eval.	End Sem	Total	Credit
STAT 10401	Statistical Inference	MDC/IDC	3-1-0	50	50	100	3

*MDC: Multi Disciplinary Core,

*IDC: Interdepartmental Core

Semester I

STAT 10101 Introductory Statistics

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1	Interpret different data collection methods and their preliminary analysis	Remember
2	Analyse important measures of central tendency	Analyse
3	Analyse various measures of dispersion and calculation of them	Understand, Analyse
4	Interpret various moments	Understand
5	Calculate skewness and kurtosis and their interpretations	Apply

Module 1: Introduction to Statistics and Data Visualization

Introduction - scope, and importance of statistics; Types of data - nominal, ordinal, interval, and ratio; Graphical representation of data-bar diagram, pie diagram, histogram, frequency polygon and ogives, box-whisker plot, Stem and leaf diagram.

Module 2: Measures of Central Tendency

Averages - Arithmetic Mean, Median, Mode, Geometric Mean, Harmonic Mean and Weighted averages. Examples and related problems for different types of data.

Module 3: Measures of Dispersion

Absolute Measures of dispersion - Range, Quartile Deviation, Mean Deviation and Standard Deviation; Combined mean and standard deviation, Relative measures of dispersion, Coefficient of Variation; Quartiles, deciles, percentiles. Examples and related problems for different types of data. Lorenz curve and Gini Index.

Module 4: Moments, Skewness, Kurtosis

Raw and Central moments, interrelationship among first four moments; Skewness - Pearson's, Bowley's and moment measure; Kurtosis;Examples and related problems for different types of data.

Reference Books:

1. Ross, S. M. (2006). *Introductory Statistics*, Second Edition, Academic Press.

2. Gupta, S. C. and Kapoor, V. K. (2017). *Fundamentals of Mathematical Statistics*, Sultan Chand and Sons, New Delhi.

3. Gupta, S.P. (2014). *Statistical Methods*, Sultan Chand and Sons.

Semester II

STAT 10201 Probability Distributions

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1	Understand the concept of probability	Understand
2	Understand the concept of random variable, pmf, pdf and cdf	Understand
3	Understand the concept of generating functions	Understand
4	Identify the situation were each of the statistical distributions are applicable	Analyse
5	Relate various statistical distributions in connection with real-life applications	Analyse

Module 1: Introduction to Probability

Sample Space, Events, Classical, Statistical and Axiomatic approaches of probability; addition theorem, conditional Probability, Independence of Events, Multiplication theorem; Bayes' theorem.

Module 2: Random Variables and Mathematical Expectation

Random variables, Probability Mass Function, Probability Density Functions, Distribution functions - Properties and Examples; Change of variables, Mathematical expectations - Definition and basic Properties; Moment Generating Function and basic properties.

Module 3: Standard Probability Distributions- Discrete type

Standard distributions: Discrete type - Uniform, Bernoulli, binomial, Poisson, geometric- mean, variance, mgf, pgf and important properties. Negative Binomial, hyper-geometric - Definition only.

Module 4: Standard Probability Distributions- Continuous type

Standard distributions: Continuous type - Uniform, Normal, exponential, gamma, beta (type I and type II)- mean, variance, mgf, pgf and important properties. Lognormal, Pareto and Cauchy - Definition only.

Reference Books:

1. Gupta, S.C. and Kapoor, V.K. (2017). *Fundamentals of Mathematical Statistics*, Sultan Chand & Sons, New Delhi.

2. Rohatgi, V.K. and Saleh, A.K.Md.K. (2015). *An Introduction to Probability and Statistics*, 3rd Edition, John Wiley & Sons Inc.

3. Ross.S. (2013). *A First Course in Probability*, 9th Edition, Pearson Education Publication.

Semester III

STAT 10301 Statistical Methods

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1	Understand the concept of bivariate random variables and probability distributions	Understand
2	Analyse different correlation and association measures	Analyse
3	Compute Chebychev's inequality	Apply
4	Use of laws of large numbers and central limit theorem	Apply
5	Differentiate different sampling distributions	Apply

Module 1: Bivariate Random Variables

Joint probability distributions, Marginal and conditional probability distributions, Independence of two random variables, Expectation of two random variables and related theorems. Conditional expectations and Problems.

Module 2: Correlation and Regression

Bivariate data, scatter diagram, Karl Pearson and Spearman Correlations; Linear Regression - Regression Equations, identification of regression lines; Measures of Association for nominal data – phi coefficient and Cramers V.

Module 3: Law of Large Numbers and central Limit Theorem

Chebychev's inequality; Weak Law of Large Numbers- Bernoulli's Law of Large Numbers; Strong Law of Large Numbers; Central Limit Theorem (De Moivre–Laplace CLT).

Module 4: Sampling Distributions

Sampling distributions: Statistic, Standard error, Sampling from normal distribution, distribution of sample mean, sample variance, chi-square distribution, t- distribution, and F distribution (definition, derivations, and relationships only).

Reference Books:

1. Gupta, S.C. and Kapoor, V.K. (2017). *Fundamentals of Mathematical Statistics,* Sultan Chand & Sons, New Delhi.

2. Rohatgi, V.K. and Saleh, A.K.Md.E. (2015). *An Introduction to Probability and Statistics*, 3rd Edition, John Wiley & Sons Inc.

3. Hogg, R.V., Mckean, J. and Craig, A.T. (2014). *Introduction to Mathematical Statistics*, 7th Edition, Pearson India Ltd.

Semester IV

STAT 10401 Statistical Inference

After completion of this course the student should be able to:

	Course Outcome (CO)	Cognitive Level
1	Apply various estimation and testing procedures to deal with real life problems	Apply
2	Discuss unbiasedness, consistency, efficiency, and sufficiency of estimators	Understand
3	Formulate and testing a hypothesis, using critical values to draw conclusions	Analyse
5	Apply large sample and small sample testing procedures and its applications	Apply

Module 1: Estimation

Point estimation, Properties of estimators – unbiasedness, consistency, efficiency and sufficiency; Methods of estimation - Maximum likelihood method, method of moments.

Module 2: Testing of Hypothesis

Testing of Hypothesis- statistical hypotheses, simple and composite hypotheses, two types of errors, significance level, p-value, power of a test, Neyman-Pearson lemma (without proof), Most Powerful Tests.

Module 3: Large Sample Tests

Z-test: test of significance for single mean and difference of means, single proportion and difference of proportions. Interval estimation of mean, difference of means, variance, single proportion and difference of proportions.

Module 4: Small Sample Tests

Student t-test: test of significance for single mean, difference of means, paired t-test, F-test for equality of population variance, Chi-square test – test for population variance, test for goodness of fit, for independence attributes.

Reference Books:

1. Gupta, S. C. and Kapoor, V.K. (2017). *Fundamentals of Mathematical Statistics,* Sultan Chand & Sons, New Delhi.

2. Gupta, S. C. and Kapoor, V.K. (2014). *Fundamentals of Applied Statistics*, Sultan Chand & Sons, New Delhi.

3. Gupta, S.P. (1999) *Statistical Methods*, Sultan Chand & Sons, New Delhi.

4. Hogg, R. V., Mckean, J. and Craig, A. T. (2014). *Introduction to Mathematical Statistics*, 7th Edition, Pearson India Ltd.

ENVIRONMENTAL SCIENCE

Learning Objectives	To provide knowledge on characteristic features and functions of the various compartments of the total environment.
	Study of pollution control acts, rules and notifications of the country and world.
	Provide knowledge on strategies for conservation of natural environment and sustainable development.

Outcome	Students will be well oriented for practicing environmental science in their carreer.

UNIT 01: Environmental 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. Air (Prevention and Control of Pollution) Act in 1981, Environmental Protection Act, 1986, The Earth Summit, Environmental agreements- The Ramsar Convention, CITES, The Kyoto Protocol, The Montreal Protocol, The Basal Convention, The Convention on Biodiversity. Sustainable development goals.

Fundamental concepts of Pollution-definition, point and non-point sources of pollution, Primary and secondary pollutants, Markers and biomarkers of water pollution, Sentinel species, Bioconcentration, Bioaccumulation, Biomagnification, central and state boards for the prevention and control of pollution in India

UNIT 02 : Atmosphere 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, greenhouse gases and global warming, photochemical smog, air quality index

UNIT 03: Hydrosphere and its Significance

Importance of water- Hydrological cycle- classification of natural waters and natural processes that affect their composition, structure and unique properties of water and environmental significance, Solubility of gases in natural waters-Henry's law, acid-base equilibria, redox and complexation reactions in water. Characteristics of natural bodies of water-pH, redox potential, alkalinity, salinity, Dissolved oxygen, Biochemical oxygen demand, Chemical oxygen demand, hardness

UNIT 04: Geosphere and its characteristics

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. Ionic ratios and interpretation of results.

UNIT 05: Biosphere and Anthrosphere

Biosphere-definition, Biotic and abiotic components, carbon seqesteration, carbon foot print, biogeochemical cycles of carbon, nitrogen and oxygen, the ecosystem concept, food chain and food web, Biomes and habitats, Autoecology and synecology, Functional role and niche, key stone species, hotspot, IUCN red list- threatened species, endangered species, vulnerable species, rare species, extinct species and endemic species, ecological succession, types of interactions-nertalism, mutualism, commensalism, parasitism, predation, herbivore. biodiversity conservation.

Anthrosphere-Definition, components of anthrosphere, technology and the environment, effects of anthrophere on earth, integration of anthrosphere into total environment, Renewable and non renewable energy sources, Sources of energy Used in the Anthrosphere-Nuclear energy, geothermal energy, Biomass energy, Energy Conservation.

References

1. Stanley E. Manahan (2017). Environmental Chemistry, 9th Edition, CRC Press Book, London.

2. APHA (2017). Standards Methods for the Examination of Water and Wastewater Analysis. 23rd Edition, APHA, Washington DC.

3. M. Harrison (2001). Pollution: Causes, Effects and Control. Fourth Edition, The Royal Society of Chemistry, Cambridge.

4. A. W. Hounslow (1995). Water Quality Data-Analysis and interpretation, Lewis Publishers, Boca Raton.

5. Pollution control acts, rules and notifications issued there under, central pollution control board, pollution control law series: PCLS/02/2010,CPCB, Delhi

6. Odum E P (1993). Fundamentals of Ecology. W B Saunders Co., USA

7. Sharma P.D., (2009) Ecology and Environment, Rastogi Publications, Meerut.

8. Negi S.S., (1993). Biodiversity and its Conservation in India. Indus Publishing Company, New Delhi.

9. Krishnamurthy K.V., (2003) A text book on biodiversity, Science Publishers, USA

10. Sharma B.K., (1994) Environmental Chemistry. Goel publication, Meerut.

11. Chapman J. L and Reiss M J (1992) Ecology - Principles and Applications, Cambridge University Press, Cambridge.

Introduction to Programming and Computation – I

Course Objective

This course provides an introduction to Programming and computational methods used in different areas of Science.

Course Outcomes: After the completion of the course the student will be able to

CO 1: Understand the Basics of Computer Architecture, hardware and software components.
CO 2: Analyze a computational problem and develop an algorithm/flowchart to find its solution.
CO 3: Develop computer programs with branching and looping statements, which uses different operators.
CO 4: Write computer programs with arrays for storing the data to be processed.

Module 1

Basics of Computer Architecture: processor, Memory, Input& Output devices

Application Software & System software: Compilers, interpreters, High level and low level languages.

Introduction to structured approach to programming, Introduction to algorithm/flowcharts and their purpose, Basic symbols and shapes used in flowcharts.

Module 2

Programming language: Introduction to C/Fortran/Python/Matlab/Octave programming, Basic concepts of programming, Programming paradigms (e.g., procedural, object-oriented), Integrated development environments (IDEs) and programming tools.

Variables, Data Types, and Operators: Variables and data storage, Basic data types (e.g., integer, float, boolean), Arithmetic, comparison, and logical operators, Type casting and type conversion.

Module 3

Control Flow Statements: If Statement, Switch Statement, Unconditional Branching using goto statement, While Loop, Do While Loop, For Loop, Break and Continue statements, Simple programs covering control flow.

Arrays and strings: Arrays Declaration and Initialization, 1-Dimensional Array, 2-Dimensional Array, Array manipulation (e.g., sorting, searching), Strings and string operations.

Text Books

1. Landau R H, Paez M J and Bordeanu C C, “A Survey of Computational Physics”, Princeton University Press (2008).
2. Stickler and Schachinger, “Basic Concepts in Computational Physics” Springer (2013).
3. Gottfried B. S., "Schaum Outline of Theory and Problems of Programming with C," 2nd EditionTata McGraw Hill (1996).

Reference Books

1. Tao Pang, "An Introduction to Computational Physics" 2nd Edition, Cambridge University Press (2006).

Introduction to Programming and Computation – II

Course Objective

This course provides an introduction to Programming and computational methods used in different areas of Science.

Course Outcomes: After the completion of the course the student will be able to

CO 1: Divide a given computational problem into a number of modules or sub-programmes and develop a readable multi-function programme to find the solution to the computational problem.
CO 2: Develop readable programs with files for reading input and storing output.
CO 3: Students will develop skills in solving problems and plot the results.

Module 1

Functions and Procedures: Introduction to functions and their role in programming, Function declaration, definition, and invocation, Parameters and return values, Recursion and recursive functions, subroutines, simple programs using functions.

Module 2

Input and Output Operations: Reading input from the user (keyboard input), Outputting results (printing to the console), File I/O operations (reading from and writing to files), Error handling and exception handling.

Debugging and Problem-Solving: Identifying and fixing errors (syntax errors, logic errors), Debugging techniques and tools, Problem-solving strategies and approaches, Breaking down problems into manageable steps

Module 3

Introduction to Plotting: Importance of data visualization, Basic Plotting Techniques, Line plots and scatter plots, Bar charts and histograms, Advanced Plotting Techniques, Area plots and stacked plots, 3D plots and Heatmaps.

Plot Customization and Styling: Plot aesthetics and design principles, Colors, markers, and line styles, Plot labels, titles, and annotations, Legends and axes customization,

Text Books

1. Gottfried B. S., "Schaum Outline of Theory and Problems of Programming with C," 2nd EditionTata McGraw Hill (1996).
2. Landau R H, Paez M J and Bordeanu C C, "A Survey of Computational Physics", Princeton University Press (2008).
3. Stickler and Schachinger, "Basic Concepts in Computational Physics" Springer (2013).

Reference Books

2. Tao Pang, "An Introduction to Computational Physics" 2nd Edition, Cambridge University Press (2006).

Introduction to Programming and Computation – III

Course Objective:

To introduce students to numerical methods and computational techniques for solving problems in various areas of Science. This will prepare them for a career in which programming and scientific computing are widely used.

Course Outcomes: After the completion of the course the student will be able to

CO 1: Develop skills in solving problems in various areas of Science using appropriate numerical methods and simulation techniques.
CO 2: Solve the Science problems with numerical interpolation techniques.

Module 1

Solution of linear and quadratic equations, matrix addition, subtraction and multiplication, trace and norm of matrix, inverse of matrix, numerical interpolation, differentiation and integration (Simpson, Trapezoidal and Gauss' Quadrature methods), Numerical errors.

Module 2

Non-linear Equations and Roots of Polynomials: Bisection method, Newton–Raphson's method, Direct Iterative method with convergence criterion.

Module 3

Numerical Interpolation and Curve Fitting: Lagrange- Hermite-, cubic spline interpolation methods and discussion on associated errors, Curve fitting by least squares.

Text Books

1. Atkinson K E, "An Introduction to Numerical Analysis", Wiley;2nd Ed. (1989).
2. DeVries P L, "A First Course in Computational Physics", John Wiley (1994).
3. Sastry S S, "Introductory Methods of Numerical Analysis", Prentice Hall (2005).

Reference Books

1. Tao Pang, "An Introduction to Computational Physics" 2nd Edition, Cambridge University Press (2006).