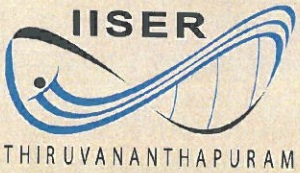


**CET CAMPUS**
Thiruvananthapuram
Kerala, India - 695 016
Tel: 0471 - 2597438
Email : contact@iisertvm.ac.in
www.iisertvm.ac.in

# INDIAN INSTITUTE OF SCIENCE EDUCATION & RESEARCH THIRUVANANTHAPURAM

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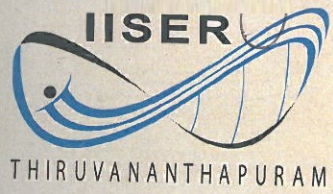


## GUIDE BOOK OF CURRICULUM AND REGULATIONS FOR THE Ph.D PROGRAMME/ THE INTEGRATED Ph.D PROGRAMME

**2012 - 2013**

# INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH THIRUVANANTHAPURAM

*An autonomous institution under the*
*Ministry of Human Resource Development, Government of India*

IISER
THIRUVANANTHAPURAM

## GUIDE BOOK OF CURRICULUM AND REGULATIONS FOR THE INTEGRATED PH. D. PROGRAMME

*2012-13*
*www.iisertvm.ac.in*

The Indian Institute of Science Education and Research (IISER) is an Institution conceived and established by the Ministry of Human Resources Development (MHRD) of the Government of India. The mission of the Institute is to offer postgraduate level teaching of the highest international standards to school leaving (+2) students and also to conduct frontline research leading to Ph.D. Degree, in basic sciences like Biology, Chemistry, Mathematics, Physics and other Interdisciplinary Science subjects.

The five IISERs established by MHRD are at Kolkata, Pune, Mohali, Bhopal and Thiruvananthapuram.

## IISER Thiruvananthapuram Campus

IISER TVM started functioning in August 2008 at the transit campus in the Department of Computer Science of the College of Engineering, Thiruvananthapuram (CET). The Institute is residential. This means all students will reside in the Institute hostels.

The phase-I construction of the permanent campus of IISER TVM at Vithura is expected to be completed in a year's time.

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# About the programme

Integrated Ph.D. Programme is a research programme. At the end of the successful completion, Master of Science and Ph.D. degree are awarded.

The first three semesters will consist of core and elective courses specialized in one subject (Biology, Chemistry, Mathematics or Physics). The fourth semester will consist of advanced courses and project work. After the successful completion of comprehensive and project work, the student will continue with research leading to the Ph.D. degree.

## Eligibility

1. A Bachelor's degree in Biological Sciences/ Chemical Sciences/ Mathematical Sciences/ Physical Sciences/ Engineering/ Technology and related areas as applicable to individual Schools, under the 10+2+3/4 system.
   Candidates admitted to School of Physics must have a valid score in Joint Entrance Screening Test (JEST).
2. The minimum requirement for admission to the programme is 55% marks or 6.0 out of 10 CGPA in the Bachelor's degree (as declared by the University).
3. The minimum requirement in the qualifying degree is relaxed to 50% or 5.5 out of 10 CGPA for SC/ST and PD candidates.

## Selection procedure

Applications for the programme will be invited through press advertisement and announcement at the Institutes' website: www.iisertvm.ac.in. Short-listed candidates who have applied for School of Biology, Chemistry and Mathematics will be called for a written test and those short-listed in the written test will appear for interview(s). In the School of Physics, candidates with a valid JEST scorecard will be called for the interview

## Enrollment

The successful candidate has to register for the Integrated Ph.D. programme by producing originals of the required certificates and payment of the registration fees on the day prescribed for Registration.

## Duration of the Programme

The maximum duration of the Integrated Ph.D. programme is 14 semesters. At the end of 14 semesters, the registration will automatically be canceled and any re-registration must have the approval of the Academic council/Senate.

## Registration

- Every student must register for the courses of a semester on the first day (registration day) of the semester.
- Registration involves payment of the prescribed fees for the semester.
- A fine of Rs.100/- per day will be levied for late registration done after the first day of class.
- Late registration after the first week of the semester can only be done with the permission of the Dean (Academics) or the Director of the institute.
- After 14 semesters, continuation of the course registration must have approval of the senate (see below).

## Fellowship

The students will be awarded Institute scholarship of Rs. 10,000/- per month until the successful completion of the coursework and comprehensive examination provided the student maintains a minimum AGPA (annual grade point average) of 6.0.

After clearing the comprehensive examination the studentship will be made equivalent to that of UGC-CSIR JRF/SRF excluding the contingency grant and HRA. The studentship will be paid for a maximum of



14 semesters (including 4 semesters of course work) for each student provided (s)he is in good academic standing.

Fellowship stands automatically terminated at the end of 14 semesters for which the student registered.

## Temporary Withdrawal

A student may temporarily withdraw from the programme, up to a maximum of two semesters in the entire duration of programme, on bona fide grounds. The withdrawal request is to be forwarded by the Faculty Advisor and Chairperson of the school (or DC) to the Dean and is to be approved by the Director.

No fellowship is provided during the period of a semester drop. The period of semester drop is not counted in the prescribed time limit for completion of the Programme.

## Leave

Student must submit an application for leave (personal/academic) to the Department Head/Director forwarded by the faculty advisor/research guide.

# Course work

## Faculty Adviser

Until the successful completion of the course work and comprehensive examination (details given below), every student is assigned a Faculty Adviser from the school who will guide the student in all academic and personal matters.

After the successful completion of the course work and comprehensive, the student's research guide will serve as the faculty adviser.

## Assessment

Continuous assessment will be adopted for all courses.

**Theory Courses** :

| | |
|---|---|
| Assignments | : 10% |
| Mid-Semester Examination-I | : 20 % |
| Mid-Semester Examination-II | : 20 % |
| End Semester Examination | : 50 % |

**Practical Courses** :

| | |
|---|---|
| Class experiments | : 70% |
| End Semester Examination | : 30 % |

## Grading

Relative grading will be adopted.

(a) The letter Grade and Grade Points are as follows:

| | |
|---|---|
| $A^+$ | 10 |
| A | 9 |
| $B^+$ | 8 |
| B | 7 |
| $C^+$ | 6 |
| C | 5 |
| D | 4 |
| F | 0 |
| I | Incomplete |

(b) Semester Grade Point Average (SGPA) is calculated as:

$$\text{SGPA} = \frac{\sum_i C_i G_i}{\sum_i C_i}$$

where, $C_i$ is the credit for $i^{\text{th}}$ course and $G_i$ = is the grade point secured by the student for the course. Summation is over all the courses credited by the student in the *semester*.

(c) Annual Grade Point Average (AGPA) is calculated as:

$$\text{AGPA} = \frac{\sum_j C_j G_j}{\sum_i C_j}$$

where, $C_j$ is the credit for $j^{\text{th}}$ course; $G_j$ is the grade point secured by the student. Summation is over all the courses credited by the student in the *academic year*.

(d) Cumulative Grade Point Average is calculated as

$$\text{CGPA} = \frac{\sum_k C_k G_k}{\sum_k C_k}$$

where, $C_k$ is the credit for $k^{\text{th}}$ course, $G_k$ is the grade point secured by the student. Summation is over all the courses credited by the student in *all the completed semesters*.



## Sample transcript

Indian Institute of Science Education and Research, Thiruvananthapuram

GRADE TRANSCRIPT

Integrated Ph.D. Programme in Biology/Chemistry/Mathematics/Physics

Name of Student: **xxxx**
Batch Name: **Batch xxxx**
Roll Number: **IPhD 0XXXX**

Grades for Varsha xxx*

| COURSE NAME | COURSE CODE | COURSE CREDIT | MAX POINTS | LETTER GRADE OBTAINED | GRADE POINTS OBTAINED | ATTENDANCE MAX 10 |
|---|---|---|---|---|---|---|
| Course I | XYZ[1] 311 | 3 | 30 | $B^+$ | 24 | 8.5 |
| Course II | XYZ 312 | 3 | 30 | $C^+$ | 18 | 8.0 |
| Course III | XYZ 313 | 3 | 30 | D | 12 | 8.8 |
| Course IV | XYZ 314 | 3 | 30 | D | 12 | 8.0 |
| Advanced Lab-I | XYZ 315 | 3 | 30 | $B^+$ | 24 | 8.9 |
| TOTAL | | 15 | 150 | | 100 | |

Semester Grade Point Average: **6.67**

Cumulative Grade Point Average: **6.67**

Date:

Thiruvananthapuram Dean, Academics

---

* *Varsha Semester: August – December, Vasanth Semester: January – May*
*Grade Points:* $A^+ = 10, A = 9, B^+ = 8, B = 7, C^+ = 6, C = 5, D = 4, F = 0,$
*I=Incomplete, M=Medical Leave*

[a] XYZ refers to BIO/CHY/MAT/PHY

## Course completion

- Students are expected to attend all classes. Students with at least 80% overall attendance will only be permitted for that end-semester examination. Attendance will be recorded in the prescribed book in every class and attendance grade will appear in the grade transcripts.
- A student with an F grade in a course may be given a repeat final examination. An F grade may be improved at best to a D grade as a result of the repeat final exam.
- If a student does not clear a course even after writing the repeat final examination, he/she is required to repeat the course with the same course number when offered next taking all examinations. Until the course is repeated and cleared by the student, it is treated as a *backlog* in the student's records.
- Repeat of a course where the grade obtained is D or above is not permitted.
- A student who has more than two F and/or I grades in any semester will have to repeat ALL the courses of that semester. Only the new grades obtained in ALL the courses will be valid.
- Make up examinations may be given to those who miss the mid semester or end semester examinations due to genuine reasons as determined by the Instructor, Dean and Director.

## MOODLE and Course Feedback

MOODLE (Modular Object Oriented Dynamic Learning Environment) is employed extensively in the teaching programmes. This includes course contents, assignments, quizzes, and course grades.

Online course feedback by students will be done for every course.



## Comprehensive examination

- At the starting of the fourth semester, the student must pass a comprehensive examination in order to continue for the Ph.D. Programme.
- In case of a failure, a repeat comprehensive examination may be given within 6 months.
- A second failure in the comprehensive examination will result in the cancellation of the registration of the student from the Integrated Ph.D. programme. Those who do not qualify to register for Ph.D. shall do another year research work to receive a Master of Science degree.

## Requirements for continuing to the Ph.D. Programme

- The minimum number of credits required for the student to continue to the Ph.D. programme is 60. Research work in the fourth semester will constitute six credits and will be graded.
- CGPA must not be below 7.
- Individual Schools are free to place additional requirements. Schools will also specify how the credits are split between theory and laboratory courses.

## Removal from the rolls

- Failure to maintain the minimum CGPA of 4.0 in any two consecutive semesters will lead to automatic removal of the student from the rolls.
- Failure to clear any CORE course even after repeating the same course a second time will lead to the removal of the student from the rolls.
- ALL courses and project work of the first two years must be successfully completed in a maximum of six semesters. Failure to do will lead to the removal of the student from the Integrated Ph.D. Programme.

*In exceptional cases the Director may at his discretion override any of the above provisions.*

# Research work

## Starting of the research work and Supervisor

After the successful completion of the first three semesters of course work and comprehensive, depending on the mutual research interest of the faculty and student, the Institute will assign a research guide(s).

The guide is primarily responsible for the research work and well being of the student.

## Doctoral Committee

Each student will have a Doctoral Committee (DC) appointed by the School/Institute. The committee will consist of the Guide, the Chairperson of the School and two other members of the IISER faculty who are in research areas related to the proposed work of the student.

Depending on the area of research and availability of courses, the doctoral committee will decide a minimum of three advanced courses which the student has to complete within the next one year.

The major role of the Committee is to monitor the progress of the research work, of the student up to the point of the award of the Ph.D. degree.

The Doctoral Committee will meet at least once every semester. At the first meeting of the Committee, the student may present a rough plan of the research work to be under taken. At every subsequent meeting, the student presents the progress of his/her work. The semester-wise report of the Committee on the student's progress is mandatory at the time of the registration of the student in each semester.

## Monitoring Research Progress

1. The Doctoral Committee will make semester-wise assessment of the progress of the research work of the student and report to the Dean (Academics).

2. In case of continued lack of progress or initiative on the part of the student, the DC may recommend the cancellation of Fellowship or termination of the Registration.
3. The DC is also empowered to recommend to the Dean any disciplinary action in case of misconduct or unethical practices.
4. In case of any dispute between the student and the guide, the DC may consider it and recommend suitable remedy.

## Research Seminars

The student has to give at least two research seminars to the department:

The first one, to be given before the end of the seventh semester, will essentially concern with the formulation of the research problem and survey of existing literature.

The second seminar, called the synopsis seminar , will discuss the major findings of the student that will go into the thesis. The synopsis seminar will be given just prior to the submission of the Thesis Synopsis to the Dean (see below) and with the approval of the Doctoral Committee.

Both the seminars will be assessed by the Doctoral Committee and will be judged as *satisfactory* or *unsatisfactory*. In the latter case, a suitable course of action will be suggested by the DC.

# Thesis submission

## Thesis Synopsis

The thesis synopsis is a Chapter-wise summary of the thesis. This is prepared after the go ahead from the DC. Each school will specify the publication requirements the student must satisfy before submission of the synopsis. The Synopsis is presented by the student to the Committee consisting of the Dean and the DC members. The synopsis is evaluated by this committee. The committee may propose revisions to the synopsis, in which case, it must be revised and resubmitted.

The accepted synopsis is further processed by the office of the Dean.

## Thesis Examination

### Selection of Examiners

The following steps are followed by the Dean, Research in processing the accepted synopsis.

1. A panel of two external examiners is confidentially selected by the Dean from a list of a minimum of four possible examiners suggested by the DC, at the synopsis evaluation meeting. The list should contain their contact details.
2. The synopsis is sent to the selected examiners by email and their willingness to examine the thesis is ascertained. If any examiner is unwilling to accept the examinership, or no response is received within a fortnight, another from the list is contacted.
3. The research guide(s) will serve as the third examiner.

### Thesis Submission

Electronic copy of the thesis produced in the prescribed format are to be submitted to the Dean's office within two months of the submission of the

synopsis. The thesis is to be forwarded to the Dean by the thesis Guide(s) and the Chairperson of the School with due certifications.

### RESEARCH PROPOSAL

In addition to the thesis, the student is to prepare a detailed research proposal not directly connected with the thesis (not more than 4000 words) and submit it to the Doctoral committee within four weeks of the submission of the Ph.D. thesis. The research proposal must provide details of the idea and supporting documentation which justifies its feasibility. The idea of the research proposal is to provide a starting point of the students' independent research career.

### THESIS EXAMINERS' REPORT

The thesis is sent to all the examiners for evaluation and for their comments on the originality and scientific merit of the findings of the author and to judge whether the work deserves the award of the PhD Degree of IISER-TVM. Specifically they will be asked to give *one* of the following verdicts:

1. The thesis is acceptable as such without any revision. I recommend the award of the Ph.D. degree of IISER-TVM to the candidate.
2. The thesis is acceptable as such without any revision. I recommend the award of the Ph.D. degree to the candidate subject to his/her satisfying the Viva Voce board about the questions/clarifications I have raised in my repor
3. The thesis needs revisions along the lines I have suggested in my report. The Ph.D. degree can be awarded to the candidate after the revisions are made to the satisfaction of the Doctoral Committee The revised thesis need not be sent to me.
4. The thesis needs revisions along the lines I have suggested in my report. I wish to see the revised thesis.



5. The thesis is not acceptable for reasons I have given in detail in my report. I do not recommend the award of the Ph.D. degree of IISER-TVM to the candidate.

### OBTAINING THESIS REPORTS

The following steps are taken by the Dean's office after sending the thesis to the examiners.

- The examiners are reminded of the report every fortnight, after an initial period of 3 weeks.
- Monthly status report of the progress of reviewing is sent to the Chairperson of the School/Department.
- If no report is received within 3 months of sending the thesis, a new examiner may be appointed by the Dean.

### FURTHER PROCESSING OF THESIS REPORTS

On receipt of both the reports, the Dean convenes the DC to discuss the reports and to take further action. The following guide lines may be observed by the DC in arriving at their decision:

- If the verdicts from the two external examiners are either (1) or (2) , the DC may recommend holding the open Viva Voce Examination.
- If the verdicts from the external examiners are both (5), the Dean, Research may constitute a committee of experts from the institute to recommend further action.
- If one of the verdicts alone is (5), a third examiner may be appointed. If the third report in this case is also (5), the Dean, Research may constitute a committee of experts from the institute to recommend further action.
- Viva Voce examination can be held only when two final reports are positive.

## Viva Voce Examination

- Once two external positive reports are received, the Dean approves the holding of an open Viva Voce Examination and appoints the Viva Board. The composition of the Board is as follows: Chairperson of the Board is the Chairperson of the School.
- Members consist of one of the thesis examiners and DC members.
- In case of the absence of the DC members, Director may appoint another member from the School.
- The examiners may seek answers to the questions raised in the thesis reports.
- At the discretion of the Director, in situations where the thesis examination is delayed and student has left the country for another assignment, thesis examination may be conducted via video conferencing.
- After the thesis presentation, the student will have to defend the *research proposal* submitted to the DC.
- The Chairperson reports the result of the Viva Voce examination to the Dean. If the Board declares the candidate to have performed satisfactorily and recommends that PhD Degree be awarded to the candidate, the Dean forwards the recommendation to the Senate of the Institute. The Senate may then recommend the award of the Degree to the Board of Governors.
- Copies of the thesis are to be deposited in the Central library and School or Departmental Libraries along with an abstract.

# Regulations

## Ethical Regulations

The student is expected to maintain high ethical standards in his/her conduct and professional work. In particular, (s)he is expected to observe the practice of acknowledging the sources of information reproduced in his/her thesis, reports, publications, or seminars. Any instance of plagiarism will attract severe punishment including the cancellation of the registration for Integrated Ph.D. or cancellation of the awarded Degree at any time.

## Conduct Regulations

1. The student must sign and submit to the Institute the following Honour Pledge at the time of registration in the Varsha semester. The pledge must be counter-signed by the parent/guardian.

IISER TVM Student Honour Pledge

a. I promise, on my honour, that I will conduct myself in the Institute and outside, with decorum and decency befitting the high moral and ethical standards expected of the members of the National Institute, IISER TVM and follow its rules and regulations
b. I will not engage in ragging. I understand that ragging is unlawful and liable to prosecution by law enforcement authorities of the State besides any disciplinary action the Institute may take which may include dismissal from the Institute.
c. I will not engage in overt/covert sexual harassment.
d. I will not resort to any dishonest practice in examinations/assignments.
e. I will not engage in plagiarism in my writings and will acknowledge the work of other authors according to international practises.
f. I will follow the Library and Hostel regulations of the Institute.
g. I understand that violation of this pledge makes me liable to disciplinary action by the Institute.

Sd/-
Student

Sd/-
Parent/Guardian

2. The student and his/her parent /guardian should sign, at the time of admission, the prescribed anti-ragging forms (see: www.iisertvm.ac.in) as per the stipulation of the MHRD, Govt. of India.

3. Use of mobile phones in the library, class rooms, laboratories and exam hall is prohibited.

## Library Regulations

1. Library hours:
    1. Library remains open from 9 AM to 7.30 PM on Monday to Friday.
    2. During Exam Week : 9 AM to 10 PM
    3. Circulation of Books will be between 9.15 AM to 5.15 PM on Monday to Friday.
    4. On Saturdays Circulation of Books will be till 12 noon; however, library remains open till 5 PM.
    5. Sundays and Holidays: Closed
2. Membership: All BS-MS students are eligible for membership at the institute library
3. Borrowing facility: BS-MS students can borrow a maximum of 4 books at a time for 2 weeks, provided they do not have any overdue book with them.
4. Users must leave their Bags and other belongings outside the Library. Only notebooks and papers are allowed inside the library. Issued books are allowed to be taken to the Library for return/renewal only. All items taken out of the library are to be produced for verification by the check point staff engaged in front of the Library.
5. Always carry the Identity card and must be produced whenever asked for.
6. Silence has to be maintained by all users in the Library.
7. Use of Mobile Phones, consumption of food and drinks are strictly prohibited in the Library.



8. Return of book is mandatory before the due date. A fine of Re.1/- per day per book for the first week of delayed return and Rs.10/- per day per book thereafter will be levied. Renewal of a book is possible only if there is no pending reservation against it. A book may be recalled anytime before the due date if it is urgently required by another member. A late fee of Rs. 10/- per day per book will be imposed for the non-compliance with the requirement.
9. Mutilation of books in any form (e.g. underlining, writing on pages, tearing off pages, damaging the binding etc) will lead to a heavy fine or even replacement of the book. Before borrowing a book users should look at the condition of the book and bring to the notice of the library staff if any mutilation found.
10. Members who lose/mutilate library materials are liable to replace the book with latest edition of the books along with a penalty of 20% of the total cost of the book. All books replaced in this manner must be of the latest edition. If the book is part of a set or series they may be called upon to replace the whole set or series. In case of the lost books is untraceable in market or out of print Library committee reserves the right to decide appropriate penalty.
11. BS-MS students should return all the books they have borrowed before they go for vacation
12. Users should obey the Library Rules and Regulations. Violation of rules and any act of misbehaviour to the library staff will be brought to the notice of the Library Committee Chair, and will lead to strong disciplinary action.

## Hostel Regulations

IISER-TVM being a residential institute, all students are expected to reside in the institute hostel throughout their course.

1. Please do not make noise in the rooms, corridors and premises of the hostel especially during night.
2. Keep your rooms and premises clean and tidy. You are responsible for keeping your rooms clean.
3. Please take utmost care not to damage furniture, TV, washing machines, building structure, electrical fittings etc.

4. Strictly avoid getting into arguments with fellow hostelites, localites and office staff.
5. Cooking inside the rooms is strictly prohibited.
6. Guests are not allowed in hostel rooms.
7. In case of any emergency (illness, accidents etc), contact the concerned warden.
8. Any overt or covert sexual/caste/religion/creed/linguistic/color remark will lead to immediate removal of the offender from the institute rolls.
9. All students must return to the hostel by 10.00 pm.
10. Bringing illegal substances such as explosives, drugs, narcotics and other illegal substances to the hostel /hostel premises is strictly prohibited.
11. Please switch off all electrical equipment after usage, if found otherwise, a fine will be levied, including recovery of cost of electrical equipment/fitting/ appliances etc.
12. Please take care of your personal belongings.
13. Anti-ragging regulations of the institute have to be strictly followed in the hostels too.
14. Leaving the hostel for a day or longer need prior permission from the concerned warden.
15. Use of drugs/alcoholic beverages/tobacco products in the hostels is strictly prohibited. Smoking in public is a punishable offence.
16. Students should be either in the hostel or in the IISER. Prior permission from the concerned warden has to be obtained in case the student need to go anywhere else. This has also to be recorded in the register kept for the purpose in the Hostel.
17. Permanent address including the phone numbers of the parent/guardian has to be given to the Warden/IISER office. Also the address has to be updated whenever there is a change due to shifting/ change of phone number of the parent etc.

# Integrated Ph.D. Curriculum

The first three semesters will consist of core and elective courses specialized in one subject (Biology, Chemistry, Mathematics or Physics). The fourth semester will consist of advanced courses and project work.

After the successful completion of comprehensive and project work, the student will continue with research leading to the Ph.D. degree.

## Course codes

The CORE and elective courses are numbered in the following format,

XYZ YSC (LTPC) XYZ YSCC (LTPC)

respectively. The numbering may be understood as

| | | |
|---|---|---|
| XYZ | : | Subject Code |
| | | BIO - Biology; CHY - Chemistry |
| | | MAT - Mathematics; PHY - Physics |
| Y | : | Year |
| S | : | Semester Number |
| C (CC) | : | Number of the course (in a particular subject) in that year |
| L | : | Lecture hours |
| T | : | Tutorial hours |
| P | : | Practical hours |
| C | : | Credits |

## Minimum Credit Requirement

The minimum number of credits required to obtain an Integrated PhD degree from IISER-TVM is 60. Over the first two years, students need to take 300 level or higher level courses. Research work in the fourth semester will constitute six credits and will be graded. CGPA must not be below 7. Individual Schools are free to place additional requirements.

Schools will also specify how the credits are split between theory and laboratory courses. In the subsequent semesters students need to register for thesis research worth zero credit.

## First four semesters

A table outlining the course requirements (sample structure only) for the first four semesters are given below. The total earned credits shown are minimum values. Individual schools may choose to offer extra courses.

### First year

SEMESTER 1

| Sl. No. | Course | Credits | Core Courses | Electives | Total |
|---|---|---|---|---|---|
| 1 | Core 1 | 3 | This Semester | This Semester | This Semester |
| 2 | Core 2 | 3 | 15 | 0 | 15 |
| 3 | Core 3 | 3 | | | |
| 4 | Core 4 | 3 | Cumulative | Cumulative | Cumulative |
| 5 | Core 5 (Lab/Theory) | 3 | 15 | 0 | 15 |



SEMESTER 2

| Sl. No. | Course | Credits | Core courses | Electives | Total |
|---|---|---|---|---|---|
| 1 | Core 1 | 3 | This Semester | This Semester | This Semester |
| 2 | Core 2 | 3 | 15 | 0 | 15 |
| 3 | Core 3 | 3 | | | |
| 4 | Core 4 | 3 | Cumulative | Cumulative | Cumulative |
| 5 | Core 5 (Lab/Theory) | 3 | 30 | 0 | 30 |

### Second year

SEMESTER 3

| Sl. No. | Course | Credits | Core courses | Electives | Total |
|---|---|---|---|---|---|
| 1 | Core 1 | 3 | This Semester | This Semester | This Semester |
| 2 | Core 2 | 3 | 12 | 3 | 15 |
| 3 | Core 3 | 3 | | | |
| 4 | Elective 1 | 3 | Cumulative | Cumulative | Cumulative |
| 5 | Core 5 (Lab/Theory) | 3 | 42 | 3 | 45 |

SEMESTER 4

| Sl. No. | Course | Credits | Core courses | Electives | Total |
|---|---|---|---|---|---|
| 1 | Elective 1 | 3 | This Semester | This Semester | This Semester |
| 2 | Elective 2 | 3 | 0 | 15 | 15 |
| 3 | Elective 3 | 3 | Cumulative | Cumulative | Cumulative |
| 4 | Research work/ Advanced Electives | 6 | 42 | 18 | 60 |

# School of Biology Curriculum

| Semester –I | | | | | | Semester -II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Course | Course Name | L | T | P | C | Course | Course Name | L | T | P | C |
| BIO 311 | Microbiology | 3 | 0 | 0 | 3 | BIO 321 | Bacterial Genetics | 3 | 0 | 0 | 3 |
| BIO 312 | Immunology | 3 | 0 | 0 | 3 | BIO 322 | Biophysics & Structural Biology | 3 | 0 | 0 | 3 |
| BIO 313 | Advanced Cell Biology | 3 | 0 | 0 | 3 | BIO 323 | Advanced Biochemistry | 3 | 0 | 0 | 3 |
| BIO 314 | Evolutionary Ecology | 3 | 0 | 0 | 3 | BIO 324 | Neurobiology | 3 | 0 | 0 | 3 |
| BIO 315 | Advanced Biology Lab-I | 0 | 0 | 9 | 3 | BIO 325 | Advanced Biology Lab-II | 0 | 0 | 9 | 3 |
| **Total** | | **12** | **0** | **9** | **15** | **Total** | | **12** | **0** | **9** | **15** |
| Cumulative credits at the end of first year: 30 | | | | | | | | | | | |
| **Semester –III** | | | | | | **Semester -IV** | | | | | |
| **Course** | **Course Name** | **L** | **T** | **P** | **C** | **Course** | **Course Name** | **L** | **T** | **P** | **C** |
| BIO 411 | Developmental Biology | 3 | 0 | 0 | 3 | BIO 421 | Advanced Molecular Biology | 3 | 0 | 0 | 3 |
| BIO 412 | Biostatistics | 3 | 0 | 0 | 3 | BIO 422 | Advanced Genetics | 3 | 0 | 0 | 3 |
| BIO 413 | Advances in Plant Biology | 3 | 0 | 0 | 3 | BIO 4201 | Elective-I | 3 | 0 | 0 | 3 |
| BIO 414 | Genomics | 3 | 0 | 0 | 3 | BIO 424 | Research Work | 6 | 0 | 0 | 6 |
| BIO 415 | Advanced Biology Lab-III | 0 | 0 | 9 | 3 | | | | | | |
| **Total** | | **12** | **0** | **0** | **15** | **Total** | | **15** | **0** | **0** | **15** |
| Cumulative credits at the end of second year: 60 | | | | | | | | | | | |

**For details of the courses offered by the School of Biology, please turn to Page (29).**



# School of Chemistry Curriculum

| Semester –I | | | | | | Semester - II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Course | Course Name | L | T | P | C | Course | Course Name | L | T | P | C |
| CHY 311 | Advanced Coordination Chemistry | 3 | 0 | 0 | 3 | CHY 321 | Organometallics Chemistry | 3 | 0 | 0 | 3 |
| CHY 312 | Quantum Chemistry | 3 | 0 | 0 | 3 | CHY 322 | Advanced Molecular Spectroscopy | 3 | 0 | 0 | 3 |
| CHY 313 | Stereochemistry-Principles & Applications | 3 | 0 | 0 | 3 | CHY 323 | Advanced Organic Chemistry-I | 3 | 0 | 0 | 3 |
| CHY 314 | Instrumental Methods | 3 | 0 | 0 | 3 | CHY 324 | Spectroscopic Methods in Structure Determination | 3 | 0 | 0 | 3 |
| CHY 315 | Advanced Organic Chemistry Lab | 0 | 0 | 9 | 3 | CHY 325 | Advanced Inorganic Chemistry Lab | 0 | 0 | 9 | 3 |
| **Total** | | **12** | **0** | **9** | **15** | **Total** | | **12** | **0** | **9** | **15** |
| Cumulative credits at the end of first year: 30 | | | | | | | | | | | |
| **Semester – III** | | | | | | **Semester - IV** | | | | | |
| **Course** | **Course Name** | **L** | **T** | **P** | **C** | **Course** | **Course Name** | **L** | **T** | **P** | **C** |
| CHY 411 | Chemistry of Solids & Materials | 3 | 0 | 0 | 3 | CHY 4201 | Elective-I | 3 | 0 | 0 | 3 |
| CHY 412 | Advanced Chemical Kinetics | 3 | 0 | 0 | 3 | CHY 4202 | Elective-II | 3 | 0 | 0 | 3 |
| CHY 413 | Advanced Organic Chemistry-II | 3 | 0 | 0 | 3 | CHY 4203 | Elective-III | 3 | 0 | 0 | 3 |
| CHY 414 | Bioinorganic Chemistry | 3 | 0 | 0 | 3 | CHY 424 | Research Work | 6 | 0 | 0 | 6 |
| CHY 415 | Advanced Physical Chemistry Lab | 0 | 0 | 9 | 3 | CHY 425 | Seminar | | | | 2 |
| **Total** | | **12** | **0** | **9** | **15** | **Total** | | **15** | **0** | **0** | **17** |
| Cumulative credits at the end of fourth year: 62 | | | | | | | | | | | |

**For details of the courses offered by the School of Chemistry, please turn to Page (43).**

# School of Mathematics Curriculum

| Semester -I | | | | | | Semester -II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Course | Course Name | L | T | P | C | Course | Course Name | L | T | P | C |
| MAT 311 | Real Analysis | 3 | 0 | 0 | 3 | MAT 321 | Complex Analysis | 3 | 0 | 0 | 3 |
| MAT 312 | Discrete Mathematics | 3 | 0 | 0 | 3 | MAT 322 | Measure Theory and Integration | 3 | 0 | 0 | 3 |
| MAT 313 | Abstract Algebra | 3 | 0 | 0 | 3 | MAT 323 | Galois Theory and Commutative Algebra | 3 | 0 | 0 | 3 |
| MAT 314 | Advanced Linear Algebra | 3 | 0 | 0 | 3 | MAT 324 | Multivariant Analysis | 3 | 0 | 0 | 3 |
| MAT 315 | Numerical Analysis | 3 | 0 | 0 | 3 | MAT 325 | Topology | 3 | 0 | 0 | 3 |
| MAT 3101 | Elective – I (Programming & Data Structures/Operations Research) | 3 | 0 | 0 | 3 | | | | | | |
| **Total** | | **18** | **0** | **2** | **18** | **Total** | | **15** | **0** | **0** | **15** |
| Cumulative credits at the end of first year: 33 | | | | | | | | | | | |
| **Semester -III** | | | | | | **Semester -IV** | | | | | |
| **Course** | **Course Name** | **L** | **T** | **P** | **C** | **Course** | **Course Name** | **L** | **T** | **P** | **C** |
| MAT 411 | Functional Analysis | 3 | 0 | 0 | 3 | MAT 4201 | Elective-III | 3 | 0 | 0 | 3 |
| MAT 412 | Probability Theory & Random Processes | 3 | 0 | 0 | 3 | MAT 4202 | Elective-IV | 3 | 0 | 0 | 3 |
| MAT 413 | Number Theory and Cryptography | 3 | 0 | 0 | 3 | MAT 4203 | Elective-V | 3 | 0 | 0 | 3 |
| MAT 414 | Theory of Ordinary Differential Equations | 3 | 0 | 0 | 3 | MAT 4204 | Elective-VI | 3 | 0 | 0 | 3 |
| MAT 4101 | Elective-II (Programming & Data Structures/Operations Research) | 3 | 0 | 0 | 3 | MAT 4205 | Elective-VII | 3 | 0 | 0 | 3 |
| MAT 415 | Reading Seminar | 0 | 0 | 3 | 1 | | | | | | |
| **Total** | | **15** | **0** | **0** | **16** | **Total** | | **15** | **0** | **0** | **15** |
| Cumulative credits at the end of second year: 64 | | | | | | | | | | | |

**For details of the courses offered by the School of Mathematics, please turn to Page (63).**



# School of Physics Curriculum

| Semester – I | | | | | | Semester – II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Course | Course Name | L | T | P | C | Course | Course Name | L | T | P | C |
| PHY 311 | Mathematical Methods | 3 | 0 | 0 | 3 | PHY 321 | Statistical Mechanics | 3 | 0 | 0 | 3 |
| PHY 312 | Classical Mechanics | 3 | 0 | 0 | 3 | PHY 322 | Condensed Matter-I | 3 | 0 | 0 | 3 |
| PHY 313 | Electronics-I | 3 | 0 | 0 | 3 | PHY 323 | Electronics-II | 3 | 0 | 0 | 3 |
| PHY 314 | Quantum Mechanics-I | 3 | 0 | 0 | 3 | PHY 324 | Electrodynamics & Special Theory of Relativity | 3 | 0 | 0 | 3 |
| PHY 315 | Advanced Physics Experiments Lab-I | 0 | 0 | 9 | 3 | PHY 325 | Advanced Physics Experiments Lab-II | 0 | 0 | 9 | 3 |
| PHY 316 | Seminar | | | | 1 | PHY 326 | Seminar | 0 | 0 | 0 | 1 |
| **Total** | | **12** | **0** | **9** | **16** | **Total** | | **12** | **0** | **9** | **16** |
| Cumulative credits at the end of first year: 32 | | | | | | | | | | | |
| **Semester – III** | | | | | | **Semester – IV** | | | | | |
| **Course** | **Course Name** | **L** | **T** | **P** | **C** | **Course** | **Course Name** | **L** | **T** | **P** | **C** |
| PHY 411 | Experimental Methods | 3 | 0 | 0 | 3 | PHY 4201 | Elective-III | 3 | 0 | 0 | 3 |
| PHY 412 | Condensed Matter-II | 3 | 0 | 0 | 3 | PHY 4202 | Elective-IV | 3 | 0 | 0 | 3 |
| PHY 413 | Quantum Mechanics-II | 3 | 0 | 0 | 3 | PHY 4203 | Elective-V | 3 | 0 | 0 | 3 |
| PHY 4101 | Elective-I | 3 | 0 | 0 | 3 | PHY 4204 | Elective-VI | 3 | 0 | 0 | 3 |
| PHY 4102 | Elective-II | 3 | 0 | 0 | 3 | PHY 424 | Research Work | 6 | 0 | 0 | 6 |
| PHY 415 | Advanced Physics Experiments Lab-III | 0 | 0 | 9 | 3 | | | | | | |
| PHY 416 | Workshop & Engineering Drawing | 0 | 0 | 3 | 1 | | | | | | |
| **Total** | | **15** | **0** | **12** | **19** | **Total** | | **18** | **0** | **0** | **18** |
| Cumulative credits at the end of second year: 69 | | | | | | | | | | | |

**For details of the courses offered by the School of Physics, please turn to Page (79).**

# School of Biology

## Theory Courses

### BIO 311 Neurobiology [3003]

Microbial characterization: diversity, nutrition, and growth in Bacteria and Fungi.

Viruses and Prions: Introduction, general characteristics, viruses of Bacteria and Archea

Microbial Physiology: Structure of microbes, autotrophic and heterotrophic metabolisms, growth and its control factors.

Microbial Genetics: Gene structure, replication, gene expression and genetic variations, extra-chromosomal genetic materials; transposition, transformation and transduction as tools in bacterial genetics.

Microbial development: Division, sporulation, organelle (flagella, pili, holdfast, chemosensory apparatus etc) development. Overview of bacterial development in the perspective of *E. coli*, *Bacillus*, *Caulobacter*, *Mycobacterium* and *Streptomyces*.

Cell-Cell communication in microbes.

Microbial Pathogenesis: Types, mode of infection with examples from *Pseudomonas aeruginosa*, *Yersinia pestis* and *Mycobacterium tuberculosis*, Antimicrobial agents and their mode of action.

Applied Microbiology: Biodegradation, Bioremediation, Fermentation, use of bacteria in recombinant production.

Textbooks/References


1. L. Sherwood and C. Woolverton, *Prescott, Harley and Klein's Microbiology*, Joanne Willey, 7-th edition
2. J. C. Pommerville, *Alcamo's Fundamentals in Microbiology*, 7-th edition
3. N. Trun and J. Trempy, *Fundamental Bacterial Genetics*, Joanne Willey, 7-th edition
4. P. Cossart, P. Boquet, S. Normark and R. Rappuoli, *Cellular Microbiology*, 2nd edition

## BIO 312 IMMUNOLOGY [3003]

Immunology an overview: Innate and adaptive Immunity.
Antigen and antibody structure and function.
T and B cell development.
T-cell receptor and antigen recognition.
Signaling through immune system receptors.
The development and survival of lymphocytes.
T cell mediated immunity.
Humoral immune response.
Response to infections: Innate, antibody response and T cell response.
Immune system gone awry: Allergies, hypersensitive reactions, Autoimmunity Vaccines.
Beyond Immunity: Antigen-antibody interactions as tools for research and therapy.
Cancer Immunotherapy.
Immunoenzymes.

TEXTBOOKS/REFERENCES

1. K. M. Murphy, P. Travers and M. Walport *Janeway's Immunobiology*, 8th Ed., Garland-Science.
2. R. A. Goldsby, T. J. Kindt and B. A. Osborne *Kuby Immunology*, W. H. Freeman and Company
3. A. K. Abbas, A. H. Lichtman and S. Pillai, *Cellular and Molecular Immunology*, 6th Ed., Elsevier.

## BIO 313 ADVANCED CELL BIOLOGY [3003]

Introduction to Cell Biology, Evolution of the Cell

Methods used in Cell Biology - Microscopy, Cell sorting, fractionation of cellular components, radioisotopes and antibodies as a tool to study cellular functions.

Cell membrane - organization and composition of the cell membrane, membrane transport, endocytosis and exocytosis.

DNA & chromosomes - packaging and organization.

Cellular organelles and function - nucleus, lysosomes, peroxisomes, golgi apparatus, endoplasmic reticulum, mitochondria, plastids and chloroplasts.



Protein targeting - Synthesis, intracellular trafficking and targeting of proteins.

Components of the cytoskeleton - organization and function of actin, intermediary filaments, microtubules and motor proteins.

Integrins, cadherins, selectins, immunoglobulin superfamily, and bacterial adhesins.

Cell-Cell signaling - overview of extracellular signaling, cell surface receptors, second messengers and regulation of signaling pathways.

Cell cycle and its control - Mechanisms of growth and division of a prokaryotic and eukaryotic cell, and cell cycle check-points.

Frontiers in Cell and molecular biology research.

TEXTBOOKS/REFERENCES

1. B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P. Walter, *Molecular Biology of the Cell* 5th Edition
2. H. Lodish, A. Berk, C. A. Kaiser, M. Krieger, M. P. Scott, A. Bretscher, H. Ploegh, P. Matsudaira, *Molecular Cell Biology* 6th edition
3. G. Karp, *Cell and Molecular Biology: Concepts and Experiments* 5th Edition

## BIO 314 EVOLUTIONARY ECOLOGY [3003]

Mechanisms of evolution

Evolution of the senses and sensory ecology

Signaling and communication in plants and animals

Asexual reproduction and the evolution of sex

Evolutionary perspectives in circadian rhythms and chronobiology

Population ecology and population genetics

Evolutionary consequences of species interactions

Community patterns I: stability, equilibrium and non-equilibrium hypotheses

Community patterns II: niche theory, metapopulations and biodiversity

TEXTBOOKS:

1. N. B. Gotelli, *A primer of ecology*, 3rd edition, Sinauer Associates, 2001

2. Charles W. Fox, Derek A. Roff, and Daphne J. Fairbairn, *Evolutionary ecology: concepts and case studies*, Oxford University Press, New York, 2001

## BIO 321 BACTERIAL GENETICS [3003]

PREREQUISITE

1. BIO 311-Microbiology

Mutations and repair in bacteria (Classes of mutations, measuring mutations, mutator strains, mechanisms of bacterial DNA repair, SOS response), Transposition, Mapping of mutations, Plasmids, Bacterial two-hybrid systems, Genetics of Bacteriophages, Recombination, Conjugation, Transformation, Transduction, Gene expression and regulation in bacteria, CRISPRs in bacteria.

TEXTBOOKS/REFERENCES

1. Larry Snyder and Wendy Champness *Molecular Genetics of Bacteria*, III Edition
2. Nancy Trun and Janine Trempy, *Fundamental Bacterial Genetics*

## BIO 322 BIOPHYSICS AND STRUCTURAL BIOLOGY [3003]

Principles of protein and nucleic acid structures:-Amino acids, proteins and their properties.Three-dimensional conformations of proteins, Ramachandran plot, motifs, folds, mechanism of protein folding, fibrous proteins, membranes, membrane proteins and their structures; Hydrogen bonding, hydrophobic interactions, ionic interactions, disulphide bonds Secondary structural elements and organisation of tertiary structure; Helix-coil transition and zipper model;Post translational modification in proteins, Hybridization,Nucleic acid structure and composition, supercoiling of DNA, denaturation and renaturation kinetics, nucleotide sequence composition: unique, middle and highly repetitive DNA; Anfinsen and the protein folding problem; How important are kinetics? action of other biologically important molecules and molecular assemblies like ribosomes, chaperones nucleosomes etc. in protein folding.

Conformational analysis:- Covalent interactions, non Covalent interactions and their roles in protein structure; Van der Waals radii of atoms



(equilibrium separation between non covalently bonded atoms) - contact distance criteria; Noncovalent forces determining biopolymer structure; dispersion; forces; electrostatic interations; van der Waals interactions; hydrogen bonds; hydrophobic interactions; distortional energies; description of various interactions by potential functions; principles of minimization of conformational energy.

Introduction to bioinformatics:- Biological databases: Organisation, searching and retrieval of information, accessing global bioinformatics resources using the World Wide Web. -bio molecular databases - sequence databases - structural databases - details of organisation, access and deposition - derived and specialised databases - data mining -homology v/s similarity - dot matrices - sequence comparison using Needleman and Wunsch method - Hash coding - BLAST and FASTA - Structure analysis - distance matrices -examples.

Physical instruments and methods in biology:-Purification and Characterization of Proteins; What does it mean to be a protein? Routes to proteins: native/recombinant/ chemical/native chemical ligation; Why is purification needed? Principles of Chromatography; Chromatography: good vs bad validation and professionalism in chromatography; Proteomic tools; are chromatographic notions changing in the present era of genomics and proteomics? Chromatographic needs of protein drugs; Characterization of molecules: large vs small; characterization of the large through fragmentation into the small: peptide mapping; characterization by coordinates in 2D gels, RPHPLC, Mass spectroscopy, Circular Dichroism, Western Blot and Bioassay.

Structural methods in NMR and Protein Crystallography for determination of macro-molecular structures: Biological NMR in Structural Biology:-Basics of NMR: Nuclear spins, chemical shifts and J couplings.Strategies for structure determination: Need for isotope labeling, High resolution multidimensional NMR, NMR experiments for protein back bone as well as side chain assignments. Distance restraints from NOE; NOESY experiments. Protein alignment; alignment medium: residual dipolar couplings (RDC); Paramagnetic effects and pseudo contact shifts; Introduction to structure calculation; Illustrative examples of protein dynamics studied using NMR.

X-ray Crystallography in Structural Biology:- X-ray diffraction, model building, computer simulation and graphics;External features and sym-

metry - unit cell and Miller indices - seven crystal systems - Bravai's lattices - point groups and space groups - X-ray diffraction - Bragg's law - Structure factors, Phase problem in crystallography, Electron density equation, Generation, detection and properties of X-rays-choice of radiation, synchrotron radiation. Introduction to protein structure determination using X-ray diffraction. Various phasing methods in crystallography, Model building, refinement and structural validation.

TEXTBOOKS/REFERENCES

1. Schulz GE and Schirmer RH, *Principles of protein structure*, Springer-Verlag
2. Branden and Tooze, *Introduction to protein structure*, Garden Publishing
3. Ramachandran & Sasisekharan, *Conformation of polypeptides and proteins*, Adv. Protein Chem. 28, 283-437, 1968
4. A. K. Downing, *Protein NMR techniques*, Methods in Molecular Biology , Volume 278, 2004
5. G.H. Stout and L.H. Jensen, *X-ray structure determination*, John; Wiley and Sons Inc., New York, 1989
6. Jan Drenth, *Principles of protein crystallography*
7. Ramachandran & Sasisekharan, *Bioinformatics methods and protocol*, Methods in Molecular Biology, Volume 132, 1998

## BIO 323 ADVANCED BIOCHEMISTRY [3003]

Exploring proteins and proteomics

Protein folding, biochemical strategies for protein purification, protein structure determination, protein-protein and protein-nucleic acid interaction; application of chromatography and mass spectrometry in characterization and identification of biological molecules.

Enzymes: understanding their catalytic and regulatory mechanism, biochemical pathways in signal transduction, biochemical strategies for enzyme inhibition

Metabolism: Glycolysis, citric acid cycle and oxidative phosphorylation, glycogen and fatty acid metabolism, protein turnover, amino acid catabolism.

Biosynthesis of amino acids, nucleic acids.

TEXTBOOKS/REFERENCES

1. Berg, Tymoczco, Stryer, *Biochemistry*, Freeman.



2. Lehninger, Cox and Nelson, *Principles of Biochemistry*, Freeman.

## BIO 324 NEUROBIOLOGY [3003]

Evolution and organization of the nervous system; Electrical properties of neurons; Ionic basis of membrane potentials and the action potential; Development of the nervous system; Synaptic transmission; Neurobiology of sensory systems; Motor functions of the spinal cord; The autonomic nervous system; Introduction to learning and memory.

TEXTBOOKS/REFERENCES

1. Kandel E, et al., *Principles of Neural Science*, 4th Ed. McGraw-Hill Medical, 2000
2. Bear M, et al., *Neuroscience*, 3rd Ed. Lippincott Williams & Wilkins, 2006
3. Sanes D, et al., *Development of the Nervous System*, 2nd Ed. Academic Press, 2005

## BIO 411 DEVELOPMENTAL BIOLOGY [3003]

Introduction to positional information, axes, coordinates and morphogen gradients.

Commonly used experimental methods in developmental biology.

Generation and Interpretation of gradient information and Pattern formation.

Physics and Mathematics of morphogen gradients and their interpretation.

Modes of cell-cell interactions during tissue organization: Self - organization, lateral inhibition, induction, and recruitment.

Growth and differentiation.

Evolution of body plan.

Stem cell biology and tissue repair.

Embryogenesis in plants: Genes controlling embryogenesis.

TEXTBOOKS/REFERENCES

1. Gilbert S.F., *Developmental Biology*, Sinauer and Associates, 2010
2. Wolpert L. et al., *Principles of development*, 3rd edition, Oxford University Press.

## BIO 412 Biostatistics [3003]

Discrete and continous distributions: Binomial, Poisson, Geometric, Normal, Exponential, Gamma and Weibul

Regression Analysis:-Linear, Non-linear, Multiple, Logisitic.

Hypothesis testing and experimental design.

Analysis of Variance and Covariance

Parametric and non-parametric statistics.

Multivariate Analysis: PCA, cluster; Time-series analysis

Textbooks/References

1. R.R. Sokal and F.J. Rohlf, *Biometry*, 3rd edition, Freeman and Co.
2. J.H. Zar, *Biostatistical Analysis*, 4-th edition, Prentice Hall, 1998.
3. G.W. Snedecor and W.G. Cochran, *Statistical Methods, 8-th edition, Blackwell.*
4. *S.M. Ross,* Introduction to Probability Models, *8-th edition, Prentice Hall, 2003.*

## BIO 413 Advances in Plant Biology [3003]

A general introduction to embryonic and post embryonic plant development, regulatory action of plant hormones in controlling the continuous patterning.

Stem cell and Regeneration: Nursery rhymes across the kingdom: regulatory network controlling the stem cell initiation and maintenance in plants, molecular mechanisms of regeneration and reprogramming of cell fate in plants

Polarity: Plant cell polarity, mechanism of onset of polarity in plant cell, hormonal flux controlling the polarity, link between cell fate and cell polarity.

Patterning: Control of organ positioning in plants, regulatory module linking phyllotaxis (shoot organ positioning) and rhyzotaxis (root organ positioning), control of organ outgrowth in plants, plant hormones controlling architecture

Evolutionary plant developmental biology: morphological diversity in different plant species utilising conserved regulatory modules.



Textbook

1. O. Leyser and S. Day, *Mechanisms in plant development*, Blackwell 2003.

## BIO 414 Genomics [3003]

Anatomy of the genome, model genomes

Scale of genome variation: mutations, SNPs, In-dels, Structural variation, ploidy changes.

Methods to study genomes: PCR, Microarrays, Next generation sequencing technologies, Comparative genomic hybridization, Pulse field gel analysis, Synthetic genetic array analysis.

Genome Mapping: Genetic markers, Genetic and physical maps, Recombination rates, Linkage analysis, Linkage Disequilibrium, Haplotype analysis, Meiotic hotspots.

Co-relating genotype with phenotype: Forward and Reverse genetics, Candidate gene approach, Insertional mutagenesis, Screening genomic libraries, Complex Trait analysis.

Genomics and Medicine: Human genome sequencing, Personalized medicine.

Genome evolution: Plasticity of Genomes, Inter-species variation, Genetic incompatibilities, Gene duplication.

Textbooks/References

1. T. A. Brown, *Genomes 3*, Garland-Science.
2. Strachan and Read, *Human Molecular Genetics*. Garland-Science
3. G. Gibson and S. V. Muse, *A Primer of Genome Science*, 3rd Ed., Sinauer.

## BIO 421 Advanced Molecular Biology [3003]

Gene Transcription.

Non-coding RNA.

Transcription regulation.

RNA processing.

Protein synthesis.

Protein folding.

Chromatin and gene expression.

Recombinant DNA technology

TEXTBOOKS/REFERENCES

1. Benjamin Lewis, *Genes IX*, Jones-Bartlett 2007.
2. David Latchman, *Gene regulation: A Eukaryotic perspective*, Stanley-Thomas Publishers 1998
3. Old and Primrose, *Principles of gene manipulation*, Wiley-Blackwell 2001.
4. Crieghton, *Protein folding*, McMillan 1993.

### BIO 422 ADVANCED GENETICS [3003]

Yeast and Mammalian genetics: Introduction to *S. cerevisiae* (yeast as a model system, cell cycle, nomenclature, yeast genome, making mutations in yeast, yeast vectors, transformation); Meiosis (Chromosome synapsis, Meiotic recombination pathways, Crossover interference); Mapping functions, Tetrad analysis, Random spore analysis; Designing yeast genetic screens, Complementation, suppression analysis, Dominant negative/high copy suppressors, Two hybrid analysis; Recombination in humans and mouse. Mapping disease genes in humans; Experiments- yeast strain construction by crossing, Estimation of recombination frequencies, gene conversion.

Bacterial genetics: Mutations and repair in bacteria (Classes of mutations, measuring mutations, mutator strains, mechanisms of bacterial DNA repair, SOS response), Plasmids, Genetics of Bacteriophages, Transposition, Recombination, Conjugation, Transformation, Transduction, Gene expression and regulation in bacteria, CRISPRs in bacteria.

Plant genetics: Combinatorial genetics for floral organ patterning, Enhancer and suppressor screens to design regulatory network, Domestication of quantitative traits in plants, Tissue specific mis-expression and Ectopic over expression studies and their implications, Genetic screens to identify upstream regulators, molecular analysis to identify downstream regulators of patterning regulators (transcription factors), Molecular genetic interactions to generate regulatory network controlling flowering time.

TEXTBOOKS/REFERENCES



1. Scott Hawley and Michelle Walker, *Advanced Genetic Analysis: Finding Meaning in a Genome*, Blackwell-Science 2004.
2. Strachan and Read, *Human Molecular Genetics*
3. Philip Meneely, *Advanced Genetic Analysis: Genes, Genomes, and Networks in Eukaryotes*, 3rd Ed., Oxford University Press.

## List of Electives in Biology

1. Cancer Biology
2. Biodiversity
3. Animal Behaviour
4. Current topics in genetics and genomics
5. Plant Morphodynamics
6. Prokaryotic development
7. Mathematical and Systems Biology
8. Viva-voce and treatise in Molecular Structural Biology

## Laboratory Courses

### BIO 315 ADVANCED LAB-I [0093]

#### Ecology

1. Designing a semester long field study on the campus, data collection, data analysis and report writing.

#### Cell Biology

1. Microscopy - Phase contrast and fluorescence; Separation of cells by density gradient; Analyses of cell cycle in bacteria; Analysis of bacterial chromosome replication by FACS; Fluorescent analysis of tubulin and actinhomologs in bacteria.

### BIO 325 ADVANCED LAB-II [0093]

#### Biochemistry

1. Identification of proteins by Western blotting
2. Purification of proteins by chromatography techniques.
3. Analysis of protein-protein interaction by biochemical techniques.
4. Determination of binding parameters of protein-ligand interaction.

**Microbiology & Molecular Biology** Gene Induction; PCR; Conjugation; Transduction; Bacterial motility assay; Mutation mapping; Construction of bacterial gene deletions by homologous recombination(including primer designing; PCR; cloning; plasmid isolation; Transformation and screening for knock-outs); Antibiotics susceptibility Testing, MIC.

**Biophysics and structural biology**

1. Basic UNIX commands, shell scripts and the first C-programming.
2. PDB and graphics visualization, basics of Visualizing molecules using Pymol, Sequence analysis at Expasy and PDB.
3. Protein Crystallization: Preparation of different forms of Lysozyme crystals with different conditions.
4. Visualizing reciprocal lattice and diffraction through Ewald sphere using X-Ray View.
5. X-ray diffraction and data collection (When X-ray in house source is available).
6. Molecular Replacement: Using AMoRestand alone package ' express mode and less automated mode.
7. Refinement of MR solution and improvement. a) Rigid body refinement b) Simulated Annealing and Positional refinement c) B-factor refinement.
8. Graphics visualization in O and model fitting. Basics of iterative cycles of model building and refinement.
9. Validation of the protein structures. Analyzing protein structures Procheck, HBPLUS, DSSP, CCP4. Intra and Inter molecular interactions - Hydrophobic effects and other interactions like hydrogen, Salt Bridges, Disulphide bonds, etc.

## BIO 415 Advanced Lab-III [0093]

1. Plant Biology:Isolation of T-DNA insertion mutant defective in plant organ formation,
2. Tissue-specific expression studies in time and space



3. Genomics:Measurement of Mutation rates in genomes. Detection of genetic incompatibilities
4. Biostatistics:Exercises in Research Methodology, Statistical ecology, Sampling, Mathematical statistics.

# School of Chemistry

## Theory Courses

### CHY 311 Advanced Coordination Chemistry [3003]

Overview on co-ordination compounds, crystal field theory (CFT) and its application for interpreting electronic and magnetic properties of co-ordination compounds, MO theory and MO diagrams of metal complexes, symmetry adapted linear combination of ligand orbitals in co-ordination compounds. Ligand field theory (LFT) applied to coordination compounds, metal-ligand $\sigma$ - and $\pi$-bonds involving s, p, d and their hybridized orbitals, $(d-p)\pi$ and $(d-d)\pi$ and $(d-d)\delta$ bonds, nature of d-d transition, MLCT and LMCT transitions in coordination compounds, dinuclear and polynuclear coordination compounds, nature of metal-metal multiple bonds including M-M quadruple and quintuple bonds, trinuclear, tetranuclear, pentanuclear and hexanuclear cluster compounds, metal string complexes.

Orgel diagrams for complexes with various $d^n$ electronic configurations, understanding electronic spectra based on Orgel diagrams, ligand field parameters, Dq, Racah parameter B and nephelauxetic constant b, evaluation of Dq and other parameters from electronic spectra, Tanabe-Sugano (T-S) diagrams for complexes with various dn configurations, nature of electronic transitions and their predictions from T-S diagrams, structure determination of coordination compounds using electronic spectra, IR and magnetic susceptibility measurements, Jahn-Teller theorem and its effect on the structural features of metal complexes.

Reactions involving coordination compounds, stability and labile nature of coordination compounds, Trans-effect, chelate effect, electron transfer reactions, inner sphere and outer sphere mechanisms, circular dichroism of coordination compounds. Photochemical reactions of coordination compounds, photoisomerisation, photosubstitution & photoredox reactions, photochemical properties of $[Ru(bipy)_3]^{2+}$ and its applications, water-splitting (to $H_2$ and $O_2$) by photo-excited coordination compounds, solar energy conversion, photovoltaic systems.

Crown ethers and cryptands and their complexation properties with metal ions, coordination polymers, metal-organic framework (MOF) compounds, their structural and materials properties, porous MOFs and their applications in gas storage and separation. Lanthanide compounds, lanthanide contraction, coordination behavior of lanthanide ions, magnetic and spectroscopic properties of lanthanide complexes, photoluminescence properties of lanthanide compounds, fluorescence emission of $Nd^{3+}$, $Eu^{3+}$, $Tb^{3+}$ compounds, Nd-YAG laser, lanthanide shift reagents. Mixed-metal oxides containing lanthanide ions and their properties, High Tc superconductors. Actinide compounds, coordination behavior of actinide elements and their coordination compounds, magnetic and spectroscopic properties.

TEXTBOOKS/REFERENCES


1. W. K. Li, G. D. Zou and T. C. W. Mak, *Advanced Structural Inorganic Chemistry*, Oxford Science Publication (2008).
2. W. W. Porterfield, *Inorganic Chemistry- A Unified Approach*, 2nd Ed., Academic Press (2008).
3. D. Banerjea, *Coordination Chemistry*, Asian Books Pvt Ltd. (2007).
4. N. N. Greenwood and A. Earnshaw, *Chemistry of Elements*, 2nd Ed.
5. N. Kaltsoyannis and P. Scott, *The f-elements*, Oxford Science Publications (2008).
6. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic Chemistry: Principles and Reactivity*, 4th Ed., Pearson Education, (2008).
7. F. A. Cotton, G. Wilkinson, C. A. Marillo and M. Bochmann, *Advanced Inorganic Chemistry*, John Wiley, (2003).
8. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, *Shriver & Atkins Inorganic Chemistry*, 4th Ed., Oxford University Press (2008).
9. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models in Inorganic Chemistry*, 3rd Ed., Wiley (1994).
10. J. E. House, *Inorganic Chemistry*, Academic Press (2008).


## CHY 312 QUANTUM CHEMISTRY [3003]

Fundamental Background: Review of postulates of quantum mechanics, Schrödinger equation and its analogy with the classical wave equation, wave functions and requirements for an acceptable wave function, operator formalism, eigenfunctions and eigenvalues, expectation values, Hermitian operators, measurement, superposition of states, commuting operators, uncertainity principle.

Exactly Solvable Problems: free particle, quasi-free particle (1-D, 2-D and 3-D box problems), concepts of quantum numbers and degeneracies, applications in organic metals, quantum wells and dots, the simple harmonic oscillator, angular momentum, the hydrogen atom problem, atomic orbitals, quantum tunneling and scattering.



The Variation Method: Rayleigh-Ritz method, simple examples like hydrogen and helium atoms, the $H_2^+$ molecule-ion, screening constants, polarizabilities, the non-crossing rule, Hartree and Hartree-Fock models, Koopman's theorem, other applications of the variation principle like LCAO-MO, molecular orbitals for diatomic molecules, block diagonalization, basis set choice and variational wavefunctions, Hückel theory and applications across organic chemistry, tight-binding approximation, WKB, Krönig-Penney model, The extended Hückel model, hybridization, why these approximations work: Hellmann-Feynman theorem.

Time Independent Perturbation Theory: Formal development of non-degenerate perturbation theory upto second order, perturbation treatment of the ground state of helium atom, comparison with the variation treatment, excited states of helium atom, electron in a wire, Zeeman and Stark effects, Crystal Field Theory, The anharmonic oscillator, perturbation theory for a degenerate state, polarizability of H-atom in the excited state, Interaction between orbitals.

Many Electron Atoms: The independent electron approximation, simple products and electron exchange symmetry, Slater determinants and Pauli principle, the self-consistent field, Slater type orbitals, Aufbau principle, spin-orbital angular momentum for many-electron atoms.

TEXTBOOKS/REFERENCES


1. J. P. Lowe and K. A. Peterson, *Quantum Chemistry*, 3rd Ed., Elsevier.
2. I. N. Levine and K. A. Peterson, *Quantum Chemistry*, 5th Ed., Prentice Hall.
3. L. Piela, *Ideas of Quantum Chemistry*, Elsevier.
4. F. L. Pilar, *Elementary Quantum Chemistry*, Dover Publications.


## CHY 313 STEREOCHEMISTRY: PRINCIPLES AND APPLICATIONS [3003]

Concept of chirality, Fisher projection formula, sequence rule, R and S notations in cyclic and acyclic compounds, optical isomerism of compounds containing one or more asymmetric carbon atoms; Stereochemistry of

biphenyls, allenes, spirans etc., conditions for optical activity, R and S notations, stereochemistry of other cyclic molecules, atropisomerism, chirality due to folding of helical structures.

Geometrical isomerism - E and Z notation of compounds with one and more double bonds in acyclic systems, inter conversion of geometrical isomers, stereochemistry of other classes of double bonded systems, asymmetric synthesis, illustration with examples. Chiral auxiliaries and chiral reagents.

Difference between configuration and confirmation, factors affecting the stability, dipole interaction, bond opposition strain, bond angle strain, representation of different conformations; Conformation of acyclic compounds, interconversion of axial and equatorial bonds in chair conformation, distance between the various H atoms and C atoms in both chair and boat conformations, stereochemistry of substituted cyclohexane and related systems, conformations of decaline, adamentane etc.

Effect of conformation on the course and rate of reactions in acyclic systems, illustration with examples, substitution, addition, elimination reduction and oxidation, reactions, important name reactions- Aldol, Perkin, Clainson, Dieckmann, Stobbe, benzoin condensation etc. Knoevenagel, Reformatosky, Wittig, Cannizaro, Mannich reactions etc., stereochemical aspects of estrification and hydrolysis.

TEXTBOOKS/REFERENCES

1. J. March, *Advanced Organic Chemistry*, 5th Ed., John Wiley and Sons, 1992.
2. E. L. Eliel, *Stereochemistry of Carbon Compounds*, Tata McGraw-Hill Edition 1975, 38th reprint 2008.
3. D. Nasipuri, *Stereochemistry of Organic Compounds-Principle and Applications*, 2nd Ed., New Age International Publishers, 2007.
4. P. S. Kalsi, *Stereochemistry-Conformation and Mechanism*, 7th Ed., New Age International Publishers, 2008.

## CHY 314 INSTRUMENTAL METHODS [3003]

Basics of measurement; Separation Techniques: Separation based on increasing number of factors (volatility, solubility, interactions with stationary phase, size, electrical field), gas and liquid chromatography, electrophoresis (plates and capillary).



Analytical Techniques: Elemental analysis, index of refraction, Flame photometry, Mass spectrometry, Infrared absorption, static and dynamic light scattering techniques, electrochemical techniques, thermoanalytical techniques, techniques in nuclear and radiochemistry (GM counter, ionizing chamber etc.).

Spectroscopic Techniques: review of optical spectroscopic techniques, linear and circular dichroism, optical rotatory dispersion, emission spectroscopy; Microscopic Techniques: Diffraction limit, optical microscopy (bright field, dark field and confocal), electron microscopy (SEM and TEM), scanning probe microscopy (STM and AFM).

TEXTBOOKS/REFERENCES

1. D. A. Skoog, F. J. Holler and T. A. Nieman, *Principles of Instrumental Analysis*, 5th Ed., Brooks Cole.
2. H. Willard, L. Merritt and J. Dean, *Instrumental Methods of Analysis*, 7th Ed., Wadsworth Publishing Company.

## CHY 321 ORGANOMETALLIC CHEMISTRY [3003]

Overview on organometallic chemistry, structure prediction based on 18-electron rule, bonding of CO using its $\sigma$-donor and $\pi$-acceptor properties and stabilization of metals in low oxidation states, metal carbonyls having both terminally bound and bridging type CO's, structural information of metal carbonyls from IR spectra, poly-nuclear metal carbonyls, carbonyl hydride complexes, metal nitrosyls, various modes of coordination of NO and its electron contribution to metals and associated structural features in such metal-nitrosyls, comparison of donor and acceptor properties of CO, NO and CN- moieties in their metal derivatives, dinitrogen and dioxygen complexes, organometallic compounds of main-group elements, Triple-decker complexes, A-frame complexes.

Structure and bonding in metal carbenes, metal olefins, metal alkynes, metal alkyls, metallocenes, half-sandwich compounds, metal-polyenes and metal-allyls, fragment molecular orbitals of various ligands and MLn moieties, detailed study on the structure and bonding in above compounds based on FMO approach, orbital interaction diagrams involving fragments in metal carbonyls, metallocenes, metal-olefins, molecular orbitals of metallocenes, stabilization of unstable moieties like carbenes, carbynes, carbides and cyclobutadiene by MLn fragments through bonding, discussions

based on orbital interaction diagrams in them, isolobal concept and comparison of various MLn moieties with non-metal fragments.

Fluxional organometallic compounds, nature of non-rigidity and their characterization by NMR spectroscopy, activation of small molecules by metal ions, reactions of coordinated ligands, synthetic and catalytic aspects of organometallic compounds, oxidative addition reactions and reductive elimination reactions, migratory insertion reactions, 1,1-migratory insertion reaction, 1,2-insertion and $\beta$-hydride elimination reactions, cyclometallation, Wilkinson's catalyst and alkene hydrogenation, Tolman catalytic loops, water-gas shift reaction, hydroformylation reactions and Heck and Breslow mechanism, Wacker process of catalytic addition of molecular oxygen to alkenes, synthetic gasoline, Ziegler-Natta polymerization of alkenes, Fischer-Tropsch process, alkene metathesis, oligomerisation of alkynes, metallacycles, ortho-metallation.

TEXTBOOKS/REFERENCES


1. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic Chemistry: Principles and Reactivity*, 4th Ed., Pearson Education, (2008).
2. F. A. Cotton, G. Wilkinson, C. A. Marillo and M. Bochmann, *Advanced Inorganic Chemistry*, John Wiley, (2003).
3. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, *Shriver & Atkins Inorganic Chemistry*, 4th Ed., Oxford University Press (2008).
4. J. P. Collman, Hegedus, Nortaon and Finke, *Principles and Application of Organo-transition Metal Chemistry*, 2nd Ed., (1987).
5. J. D. Atwood, *Inorganic and Organometallic Reaction Mechanism*, 2nd Ed., Wiley-VCH (1997).
6. R. H. Crabtree, *The Organometallic Chemistry of Transition metals*, Wiley, New York (1988)
7. M. Bochmann, *Orgaonometallics and Complexes with Transition Metal-Carbon Sigma Bonds*, Oxford Science publications (2005).
8. R. C. Mehrotra and A. Singh, *Organometallic Chemistry-A Unified Approach* 2nd Ed., New Age International Publication (2000).
9. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models if Inorganic Chemistry*, 3rd Ed., Wiley (1994).
10. W. K. Li, G. D. Zou and T. C. W. Mak, *Advanced Structural Inorganic Chemistry*, Oxford Science Publication (2008).




## CHY 322 ADVANCED MOLECULAR SPECTROSCOPY [3003]

Group theory: Symmetry elements and operations, rotation axes, reflection planes, inversion centres, products of symmetry operations, groups and classes, symmetry point groups and examples, the great orthogonality theorem, character tables, direct products, projection operators, symmetry adapted linear combinations.

Interaction of radiation with matter: Electromagnetic radiation, radiation density and intensity, theory of blackbody radiation, correlation to the Einstein coefficients of absorption and emission, time dependent perturbation theory, Fermi golden rule, lineshape functions, homogeneous and inhomogeneous broadening, lasers.

Introduction to Molecular Spectroscopy: Molecular Hamiltonian, Born-Oppenheimer approximation. Rotational spectroscopy: Nuclear motion in diatomics, separation of translational and relative motion, rotation of rigid bodies, moment of inertia, linear molecules, spherical, symmetric and asymmetric tops, selection rules, rotational spectra and line intensities, molecule and space fixed coordinate systems, structure determination from rotational constants, isotopic effects.

Vibrational Spectroscopy: Review of vibrational motion in diatomics, vibrational selection rules, dissociation energies, vibration-rotation transitions in diatomics, Beyond the rigid rotor-harmonic oscillator approximation using perturbation theory, anharmonicity and Morse oscillator, centrifugal distortion, nuclear spin and the Pauli principle, ortho and para modifications of homonuclear diatomics, vibrational motion of polyatomics, internal coordinates, symmetry coordinates, normal coordinates, The Wilson F and G matrices, group theoretical treatment of vibrations.

Raman Spectroscopy: Review of light scattering and Raman effect, classical and quantum models for scattering, polarizability tensor, selection rules, mutual exclusion rule for centrosymmetric molecules, Rayleigh and Raman intensities, resonance Raman scattering.

Electronic Spectroscopy of molecules: Molecular orbitals as LCAOs, electronic spectroscopy of diatomics, orbitals and states, term symbols, parity of diatomic energy levels, selection rules, vibrational and rotational structures, Frank-Condon principle, dissociation, photodissociation and predissociation, electronic spectroscopy of polyatomic molecules, Walsh's rules, Huckel molecular orbital theory, vibronic coupling.

TEXTBOOKS/REFERENCES

1. P. F. Bernath, *Spectra of Atoms and Molecules*, Oxford University Press.
2. J. L. McHale *Molecular Spectroscopy*, Pearson Education.
3. I. N. Levine, *Molecular Spectroscopy*, John Wiley & Sons.
4. J. M. Hollas, *Modern Spectroscopy*, John Wiley & Sons.
5. W. W. Parson, *Modern Optical Spectroscopy*, Springer-Verlag.

## CHY 323 ADVANCED ORGANIC CHEMISTRY I [3003]

Pericyclic reactions: Pericyclic reactions, four classes of pericyclic reactions, symmetry allowed and symmetry forbidden reaction, Woodward-Hoffmann rules in (i) cycloaddition (ii) Electrocyclic reactions (iii) sigmatropic reactions (iv) group transfer reactions. generalized Woodward-Hoffmann rules in (i) cycloaddition (ii) electrocyclic reactions (iii) sigmatropic reactions (iv) group transfer reactions. Symmetry allowed but geometrically unreasonable reactions, geometrically reasonable but symmetry forbidden reactions, reactions of ketenes, allenes, carbenes. Explanations for Woodward-Hoffmann rules, aromatic transition state structure, frontier orbitals, correlation diagrams.

Thermal Pericyclic reactions: Diels Alder reaction, requirements of diene and dienophiles, endo rule, regioselectivity, regioselectivity of hetero Diels-Alder reaction, stereoselectivity of Diels-Alder reaction, effect of Lewis acid on Diels-Alder reaction, intramolecular Diels Alder reaction. 1,3-dipolar cycloaddition, other cycloadditions, osmylation, ozonolysis. Other pericyclic reactions: sigmatropic rearrangements, Electrocyclic rearrangements, Ene reaction. Periselectivity and torquoselectivity.

Photochemical Pericyclic reactions: photochemical pericyclic reactions, photochemical Woodward-Hoffmann rule, regioselectivity in photocycloadditions: Paterno-Buchi reaction, photodimerization of alkenes, photochemical cross coupling of alkenes, photocycloaddition to aromatic ring. Other kinds of selectivity in pericyclic and related photochemical reactions: electrocyclic reactions, sigmatropic rearrangements. Asymmetric synthesis: resolution, chiral pool, asymmetric synthesis, chiral reagents and chiral catalysts. Chemoselectivity: Reducing agents, reduction of carbonyl groups, catalytic hydrogenation, dissolving metal reductions, kinetic/thermodynamic control, oxidizing agents.

Controlling geometry of double bonds: Unselective elimination, Julia olefination, Peterson elimination, Wittig reaction, steroselective addition to alkynes.



Stereoselective reactions of cyclic compounds: Stereochemical control in 6-membered ring, conformational control in the formation of 6-membered rings, sterochemistry of bicyclic compounds, fused bicyclic compounds, spirocyclic compounds, reactions with cyclic intermediates or cyclic TS. Diastereoselectivity: Steroeselectiv ereactions, prochirality, diasteroselctive addition to carbonyl groups, chelation controlled stereoselectivity, steroselective reactions of scyclic alkenes, steroselective aldol reactions.

TEXTBOOKS/REFERENCES

1. I. Fleming, *Molecular orbitals and Organic chemical reactions*. Student Ed., Wiley VCH.
2. R. Bruckner, *Advanced organic chemistry, Reaction mechanisms*, Academic Press.
3. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic chemistry*, Oxford University Press. .

## CHY 324 SPECTROSCOPIC METHODS IN STRUCTURE DETERMINATION [3003]

Nuclear Magnetic Resonance Spectroscopy: Principle of NMR, common spin 1/2 nuclei, Zeeman splitting, Boltzmann distribution, effect of magnetic field strength on sensitivity and resolution, 1H-NMR, chemical shift, anisotropic effects, chemical and magnetic equivalence, coupling constants, Applications: Karplus relationship of J on dihedral angle, first order J splitting patterns and structure correlation, Strong coupling effects, 13C satellites, 13C-NMR, natural abundance, sensitivity, 13C chemical shifts and structure correlations. INEPT, DEPT and INADEQUATE pulse sequences, application of two-dimensional NMR, COSY, NOESY experiments for connectivity information and illustrative examples in organic molecule structure determination, dynamic processes by NMR, restricted rotation, cyclohexane ring inversion, introduction to 31P and 19F NMR.

ESR spectroscopy: ESR spectra of organic free radicals and ion radicals, transition metal complexes. Mass spectrometry: Basic principles, ionization methods, isotope abundance, molecular ions, factors governing fragmentation processes, examples of common types of fragmentation processes and deduction of structural information, high resolution MS.

Infrared and UV spectroscopy: Review of basic principles, classification of UV absorption bands, examples of UV chromopheres, vibrational modes, general features of IR spectra, group frequencies of organic systems, factors affecting the group frequencies, study of hydrogen bonding effects, vibrational spectra of ionic, coordination and metal carbonyl compounds. Illustrative examples of structure elucidation from spectra.

TEXTBOOKS/REFERENCES

1. R. M. Silverstein, G. C. Bassler and T. C. Morril, *Spectrometric identification of organic compounds*, John Wiley, 1991.
2. W. Kemp, *Organic spectroscopy*, 2nd Ed., ELBS, Hongkong, 1987.
3. L. D. Field, S. Sternhell and J. R. Kalmann, *Organic structures from spectra*, John Wiley, 2007.
4. M. H. Levitt, *Spin Dynamics*, 2nd Ed., John Wiley, 2007.
5. S. Braun, H. O. Kalinowski and S. Berger, *100 and more basic NMR experiments*, VCH, Weinheim, 1996.
6. D. Neuhaus and M. Williamson, *The Nuclear Overhauser effect in structural and conformational analysis*, VCH, New York, 1989.

## CHY 411 CHEMISTRY OF SOLIDS AND MATERIALS [3003]

Structures of Solids: Crystal structures, close packing, body centered and primitive structures. Symmetry in crystals, crystallographic point groups, space groups, reciprocal space, Brillouin zones, lattices, one and two dimensional unit cells, translational symmetry elements, Three dimensional unit cells, Miller indices, interplanar spacings, packing diagrams. Structures of Important Ionic Solids: Ionic Radii, ionic solids with formula MX (CsCl, NaCl, NiAs, Zinc Blende and Wurtzite Structures), $MX_2$ (Fluorite and Antifluorite Structures, Cadmium Halides, Rutile, Anti-rutile, $\beta$-cristobalite), other crystal systems (Bismuth tri-iodide, Corundum, Rhenium Trioxide etc.), mixed oxides (Spinel, Perovskite, Ilmenite). Non-Ionic Solids: Covalent solids, molecular solids and dispersion interactions, Pauling ice rules, silicates, phosphates, arsenates and related extended systems, zeolites, mesoporous materials, clay, metallo-Organic and related open framework materials (MOF), hybrid materials, reticular chemistry.

Defects and Dislocations in Solids: Point defects, dislocations, geometrical representation of various types, grain boundary, phase boundary, examples in alloys and materials; Synthesis of Solids: Gas to Solid Synthesis: Vapour deposition, chemical vapour deposition (CVD/MOCVD), sputtering. Liquid to Solid Synthesis: Crystal growth from melt, liquid quenching, sol-gel methods, ion-exchange and intercalation. Solid to Solid Synthesis: Solid state reactions, high pressure synthesis, glass, ceramics. Other Methods: Microwave reactions, combustion synthesis, hydrothermal methods, high temperature superconductors.



Electronic Structure of Solids: Free electron theory, Drude model, concept of Fermi level, density of states, band structure, periodic potentials in solids, Kronig-Penney Model, Bloch Functions, tight binding (TB) model, some Exact results, LCAO for monoatomic chain, binary chain (Peierls Theorem), the effective mass concept, direct and indirect band gaps, TB model solutions for square lattice and honeycomb lattice (graphene), the Hall effect, band structure for some simple solids: AgCl, KCl, $ReO_3$, Si, electronic structure of metals and alloys, Fermi Surface, explanation for Hume-Rothery rules, analysis of Bands, partial density of states (PDOS) and crystal orbital overlap population (COOP).

Magnetic and Dielectric Properties of Solids: Magnetization, types of magnetic materials, order-disorder transitions, Curie law and Curie-Weiss law, band electron theory for magnetism, Pauli paramagnetism, exchange coupling, spin-up and spin-down half bands, band model for transition metal alloys, the localized electron model for magnetism (lanthanides), mean field approximation, giant, tunneling and colossal magnetoresistance, electrical polarization, piezoelectric crystal, $\alpha$-quartz, ferroelectric effect, multilayer ceramic capacitor.

TEXTBOOKS/REFERENCES

1. A. R. West, *Solid State Chemistry*, Wiley Student Ed., (2003) (Indian Ed.).
2. C. N. R. Rao and J. Gopalakrishnan, *New Directions in Solid State Chemistry*, 2nd Ed., Cambridge University Press (1987).
3. L. E. Smart and E. A. Moore, *Solid State Chemistry: An introduction*, 3rd Ed., Taylor and Francis, 2010 (Indian Ed.)
4. P. A. Cox, *The Electronic Structure and Chemistry of Solids*, Oxford Science Publications (1987).
5. D. Jiles, *Introduction to the Electronic Properties of Materials*, 2nd Ed., 2010, Nelson Thornes Ltd. (Indian Ed.)
6. G. Gottstein, *Physical Foundations of Materials Science*, Springer (2004).

SUGGESTED READING

1. R. Hoffmann, *Solids and Surfaces: A chemist's view of bonding in extended structures*, Wiley-VCH, 1988.

2. N. W. Ashcroft and N. D. Mermin, *Solid State Physics*, Brooks-Cole (1976).
3. S. Elliot, *The Physics and Chemistry of Solids*, Wiley India (1998).

## CHY 412 ADVANCED CHEMICAL KINETICS [3003]

Introductory kinetics: Determination of order of reaction, complex reactions, integration of rate equations, opposing reactions, parallel reactions, and consecutive reactions, methods of analysis, measurement of rates, replacement of time with area variable, the Laplace transform, secular equation and eigen values, the steady state approximation.

Theory of chemical kinetics: Kinetic theory of collisions, macroscopic reaction rates from microscopic properties, collision cross section, potential energy surfaces for various reactive and nonreactive scattering processes, conventional transition state theory, Eyring equation, elementary gas phase reactions, Lindemann - Hinshelwood mechanism and the Rice-Ramsperger-Kassel-Marcus (RRKM) theory for unimolecular reactions, Kramers' theory, Marcus' electron transfer theory, and information theory.

Reactions in solution: Nature of liquids, effect of pressure, dielectric constant and ionic strength, state-to-state dynamics, molecular beams. Chain reactions: normal and branched chains, explosion reactions, Rice-Herzfeld mechanism, Goldfinger scheme, free radical polymerisation. Acid-Base Catalysis: Specific and general catalysis, Skrabal diagram, prototropic and protolytic mechanisms, secondary salt effect, examples, Acidity function, HO, H-scales, overlap method, mechanism.

Fast reaction kinetics: relaxation methods, large perturbation, flash photolysis, lasers photolysis, pulsed radiolysis, small perturbation. Kinetics in the excited electronic states: Jablonskii diagram, kinetics of unimolecular photophysical and photochemical processes, photoisomerisation, bimolecular photophysical and photochemical proceses, excimers, exciplexes and sensitisation; Time scales of photophysical processes, primary quantum yield, photostationary states, mechanism of the decay of singlet excited state and Stern-Volmer equation, resonance energy transfer, light induced electron transfer and Marcus equation; Laser photochemistry including pulsed laser and multiphoton excitation, laser flash photolysis in various time scales. Kinetics of natural light induced processes including photosynthesis and vision, designing of light induced systems and tuning



of their rates, light induced processes and environment; Radiation chemical processes including pulse radiolysis, hydrated electrons, chemiluminescence.

Surface reaction kinetics : Physical and chemical adsorption, adsorption isotherms, Langmuir-Hinshelwood and Eley-Rideal mechanism, heat of adsorption, kinetics of solid state reactions.

TEXTBOOKS/REFERENCES

1. K. J. Laidler, *Chemical Kinetics*, 3rd Ed., Pearson Education (Indian Ed.).
2. M. R. Wright, *An Introduction to Chemical Kinetics*.
3. J. Rajaram and J. C. Kuriacose, *Kinetics and mechanism of chemical transformation*, Macmillan India.
4. S. K. Upadhyay, *Chemical Kinetics and Reaction Dynamics*, Springer.
5. G. D. Billing and K. V. Mikkelsen, *Introduction to Molecular Dynamics and Chemical Kinetics*.
6. P. Atkins, *Physical Chemistry*, 8th Ed., Oxford University Press.
7. N. J. Turrro, V. Ramamurthy and J. C. Scaiano, University Science Books.
8. J. R. Lakowicz, *Principles of Fluorescence Spectroscopy*, 3rd Ed., Springer.

## CHY 413 ADVANCED ORGANIC CHEMISTRY II [3003]

Saturated Heterocycles: Introduction, reaction of heterocycles, conformation of saturated heterocycles, anomeric effect, ring closing reactions to make heterocycles; Aromatic heterocycles: pyrroles, thiophenes, furans, pyridines, pyrazoles, pyridazines, pyrimidines, isoxazoles, tetrazoles, quinolines, isoquinolines, Fischer Indole synthesis; Chemistry of Life: Primary metabolism, carbohydrates, nucleosides, nucleotides nucleic acids, Aminoacids, peptides, proteins, lipids.

Polymerization: Monomers, dimers, oligomers, polymerization by carbonyl substitution, polymerization by electrophilic substitution, polymerization by SN2 reaction, polymerization by nucleophilic attack on isocyanates, polymerization of alkenes, co-polymerization, cross-linked polymers, reaction of polymers, Biodegradable polymers and plastics.

TEXTBOOKS/REFERENCES

1. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic chemistry*.

### CHY 414 BIOINORGANIC CHEMISTRY [3003]

Occurrence, availability and biological functions of inorganic elements in organisms. Biological functions of various metal ions. Biological ligands for metal ions. Function and transport of $K^+, Na^+, Ca_2^+$ and $Mg_2^+$ ions in biological systems. Complexes of alkali and alkaline earth metal ions with macro-cycles. Ion channels. Ion pumps. Catalysis and regulation of bio-energetic processes by alkaline earth metal ions. Coordination by proteins and enzymatic catalysis. Tetrapyrrole ligands and other macrocycles. Metals in the centre of photosynthesis-Mg and Mn. Photosynthetic process. Mn- catalysed oxidation of water to $O_2$. Cobalamines including vitamin and coenzyme $B_{12}$. Reactions involving coenzyme B12.

Uptake, transport and storage of dioxygen. Haemoglobin and myoglobin and their functions. Cooperative effect in haemoglobin. Perutz mechanism. Haemerythrin and haemocyanin. Catalysis through hemoproteins. Electron transfer, oxygen activation and metabolism of inorganic intermediates. Cytochromes. Cytochrome P-450 and oxygen transfer from $O_2$ to non-activated substrates. Catalases and peroxidases. Generation and function of organic free radicals.

Uptake, transport and storage of iron, Fe-S and other non-heme iron proteins. Ferredoxins, transferrin, ferritin. Ni-containing enzymes. Copper containing proteins. Type 1 blue copper centres. Type 2 and type 3 copper centres in $O_2$-activating proteins. Mo-containing enzymes. Zinc in biological systems, metalloenzymes. Carboxypeptidase A. 'Zinc-finger' and other gene regulatory Zn-proteins.

Bio-mineralization. Biological functions of the non-metallic inorganic elements. Bioinorganic chemistry of the quintessentially toxic metals. Chemotherapy with compounds of some non-essential elements. Cis platin and its mode of action. Gold-containing drugs. Photodynamic therapy. Biomimetic chemistry. Model compounds. Metalloporphyrins, picket-fence porphyrins, capped porphyrins.

TEXTBOOKS/REFERENCES

1. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic Chemistry: Principles and Reactivity*, 4th Ed., Pearson Education, (2008).
2. F. A. Cotton, G. Wilkinson, C. A. Marillo and M. Bochmann, *Advanced Inorganic Chemistry*, John Wiley, (2003).



3. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, *Shriver & Atkins Inorganic Chemistry*, 4th Ed., Oxford University Press (2008).
4. J. D. Atwood, *Inorganic and Organometallic Reaction Mechanism*, 2nd Ed., Wiley-VCH (1997).
5. M. Bochmann, *Orgaonometallics and Complexes with Transition Metal-Carbon Sigma Bonds*, Oxford Science publications (2005).
6. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models if Inorganic Chemistry*, 3rd Ed., Wiley (1994).
7. W. Kaim and B. Schwederski, *Bioinorganic chemistry: Inorganic Elements in the Chemistry of Life*, Wiley (2006).

### LIST OF ELECTIVES IN CHEMISTRY

**Details of the electives will be announced later.**

## Laboratory Courses

### CHY 315 ADVANCED ORGANIC CHEMISTRY LABORATORY[0093]

1. Separation and quantification of ternary mixtures. Determination of purity by melting points and TLC. Mixtures No. 1-4
2. SN1 and SN2 reactions
3. (a)Determination of moisture content in the organic solvents using Karl-Fischer titration
   (b)Drying of organic solvents
4. Estimation of nitrogen in the given organic compound by Kjeldahl's method
5. Extraction of eugenol from cloves by steam distillation
6. Cycloaddition reaction: (Diels- Alder reaction) Diels-Alder reaction of furan and N-phenylmaleimide, preference for endo or exo-product formation
7. (a)Claisen-Schimidt reaction- Preparation of benzal acetophenone
   (b)Malonic ester synthesis- cyclobutane carboxylic acid
8. Multistage preparations and spectroscopic characterization
   (a)Conversion of bromobenzene to triphenyl carbinol and then to tritylchloride
   (b)Preparation of vanilline and its derivatives fron p-hydroxybezaldehyde
   (c)Benzaldehyde to methylstyrene and to 1-phenyl 1,2-dihydroxypropane

(d)Preparation of benzotriazole from o-nitroaniline
(e)Preparation of sys-tribromobenzene from aniline
(f) Validity of Huckel's 4n+2 rule: Synthesis of triphenyl methyl fluoroborate and tropyllium iodide
(a)Chemiluminesence: Synthesis of cyalume and chemiluminescence

9. Molecular rearrangement

(a)Green photochemical reaction (Photoreduction of benzophenone to benzopinacol and then to benzopinacolone)
(b)Rearrangement of diazoaminobenzene to p-aminoazobenzene
(c)Benzil Benzilic acid rearrangement
(d)Preparation of caprolactum from cyclohexanone and nylon-6

10. Ionic liquids

- Preparation of tetrabutylammonium tribromide (TBATB) and Bromination of Chalcone
- Preparation of 1-pentyl-3-methylimidazolium bromide (pmIm) and Preparation of 2-phenylbenzothiazoles catalyzed by ionic liquid.

11. Phase transfer catalyst

- Wittig reaction: The preparation and purification of trans-stilbenes

12. Microwave oven assisted organic syntheses
13. Multi-step synthesis coenzyme catalyzed synthesis of Benzoin and derivatives

- Part 1: Synthesis of Benzoin
- Part 2: Synthesis of Benzil
- Part 3: Synthesis of Benzilic Acid
- Part 4: Synthesis of Benzoic acid from Benzaldehyde

## CHY 325 Advanced Inorganic Chemistry Laboratory[0093]

1. Simple Gravemetric analysis of Ni, Cu, etc.
2. Synthesis of a solid acid, 12-Tungstosilicic acid, $H_4$ Si $W_{12}O_{40}.7H_2O$

- Synthesis of Zeolite ZSM-5



3. The preparation of Potassium tris(oxalato) ferrate(III) trihydrate $K_3[Fe(C_2O_4)_3]$ and its characterization
4. The Mechanism of Aquation of trans - dichlorobis (1, 2 - diaminoethane) cobalt(III) chloride
5. Preparation of Ferrocene and its reactions
6. Sequential synthesis of several complexes containing Mo – Mo quadrupole bond
7. Synthesis and reactions of Potassium tetrathionate
8. Synthesis and magnetic properties of tetragonal Ni(II) complexes
9. Synthesis of Co(III) complexes and characterization
10. Microwave assisted synthesis of 5,10,15,20 - tetraphenylporphyrin
11. Synthesis and characterization of an oxygen-carrying Cobalt complex which mimics Haemoglobin
12. Binding of a small molecule to a Metalloprotein: Determination of the Equilibrium Binding Constant
13. Reduction potential of cytochrome C
14. Ammonia-Borane related N-B-H compounds and materials
15. Olefin epoxidation with Mn (salen complex)
16. Synthesis and kinetics study of Wilkinson's catalyst
17. Studies on ligand field strength: Chromium complexes with ligands of different ?0
18. Common geometries of pentacoordinate complexes: preparation of acetylacetonate complexes

## CHY 415 Advanced Physical Chemistry Laboratory[0093]

1. Determination of molecular weights by cryoscopic method

(a)using water
(b)benzene
(c)Camphor as the solvents

2. Viscosity measurements

(a)Determination of coefficient of viscosity using Ostwald's viscometer
(b)Variation of viscosity of a liquid with temperature

(c) Verification of J. Kendall's equation and determination of the composition of a mixture of two liquids
(d) Determination of radius of glycerol molecule
(e) Determination of molecular weight of polymers

3. Surface tension

(a) Determination of surface tension of the liquid by drop weight and drop number method
(b) Determination of the composition of two liquids by surface tension measurements
(c) Determination of limiting cross sectional area by surface tension method
(d) Determination of atomic parachor

4. Thermochemistry

(a) Determination of heat of neutralization of strong acid against strong base
(b) Determination of heat of neutralization of weak acid and hence its heat of ionization
(c) Determination of calorific value of fuels using bomb calorimeter

5. Refractometry

(a) Determination of refractive index of liquids and hence specific and molar refraction
(b) Determination of molar refractivity of liquids and hence refraction equivalents of C, H and Cl atoms and refraction equivalent of -$CH_2$ group
(c) Determination of molar refraction of solid by dissolving in a liquid

6. Spectophotometry

(a) Test the validity of Beer-Lambert's law
(b) Determination of composition of binary mixture of $KMnO_4$ and $K_2Cr_2O_7$
(c) Determination of dissociation constant of weak acid/ weak base
(d) Study the complex formation between Fe(III) and salicylic acid, and find the formula and stability constant of the complex
(e) Investigate the complex formation of (a) Fe(III) and thiocyanate (b) Ni(II) and ethylenediamine by Job's method



7. Dipole measurement

(a) Determination of dipole moment of liquids and variation of dipole moment with temperature

8. Equilibrium and dissociation constant

(a) Determination of equilibrium constant of keto-enoltautomerisation of ethyl acetoacetate
(b) Determination of equilibrium constant of esterification reaction between acetic acid and ethanol.
(c) Determine the equilibrium constant of the reversible reaction $2Ag^+ + CaSO_4 \rightleftharpoons Ag_2SO_4 + Ca^{2+}$

9. Chemical Kinetics

(a) Study the kinetics of iodination of acetone by (a) Visual (b) Titrimetric and (c) Spectrophotometric methods
(b) Electrochemistry

10. Electrolytic conductance

(a) Determination of dissociation constant of weak acid
(b) Determination of solubility of sparingly soluble salt
(c) Verification of Onsagar equation.

11. Transport number

- Determination of transport number by moving boundary and Hitroff methods

12. Electromotive force

(a) Single electrode potential and verification of Nernst equation
(b) Thermodynamics of electrochemical cells
(c) Determination of equilibrium constant
(d) Determination of solubility of sparingly soluble salt.

13. Surface Chemistry

- Adsorption of oxalic acid/ acetic acid on charcoal and verification of Freundlich and Langmuir's adsorptionisotherms

14. Fuel Cells

- Determination of Faraday efficiency and Energy efficiency

15. Corrosion
    - Determination of rate of corrosion of a material at different conditions
16. Concept of particle in a box
    - Determination of C = C length from absorption spectra of conjugated dienes.
17. Electronic potential energy surfaces
    - Absorption spectra of molecular iodine, calculation of vibrational frequencies, anharmonicities and bond energies.
18. Polarimetry
    (a) Rate constant of hydrolysis of cane sugar
    (a) Determine the percentage of two optically active substances in a given solution
19. Dissociation equilibria of ampholites and determination of isoelectric point

# Mathematics Syllabus

**MAT 311: Real Analysis [3003]**

Metric spaces: Properties and examples, supremum, infimum, neighbourhood, open sets, limit points, Bolzano-Weierstrass theorem, derived sets, closed sets, adherent points, closure of a set, nested intervals, Cantor intersection theorem, cover, open cover, sub cover, Heine-Borel theorem, converse of Heine-Borel theorem, compact sets, connected sets, convergent sequences, subsequences, Cauchy sequences, completeness, continuous functions, continuity and compactness, continuity and connectedness.

The Riemann-Stieltjes integral: Functions of bounded variation, total variation, bounded variation functions as difference of monotone functions, continuous functions of bounded variations, partitions, definition of Riemann-Stieltjes integral, refinement, existence of the integral, properties of the integral, fundamental theorems of integral calculus, mean value theorems, integration by parts.

Sequences and series of functions: Pointwise and uniform convergence, uniform convergence and continuity, uniform convergence and integration, uniform convergence and differentiation, sufficient condition for uniform convergence of a series, equicontinuity, Ascoli's theorem, Stone-Weierstrass theorem.

TEXTBOOKS/REFERENCES

1. Walter Rudin, *Principles of Mathematical Analysis*, 3rd Edition, McGraw-Hill, 1976.

2. T.M. Apostol, *Mathematical Analysis*, 2nd Edition, Addison Wesley, 1974.
3. Terence Tao, *Analysis II*, Hindustan Book Agency, 2006.
4. Richard R. Goldberg, *Methods of Real Analysis*, 2nd Edition, Wiley, 1976.
5. Serge Lang, *Undergraduate Analysis*, 2nd Edition, Springer, 1996.
6. R.G. Bartle and D.R. Sherbert, *Introduction to Real Analysis*, 4th Edition, Wiley, 2011.
7. S.R. Ghorpade and B.V. Limaye, *A Course in Calculus and Real Analysis*, Springer, 2006.

## MAT 312: Discrete Mathematics [3003]

Propositional logic, truth tables, predicates and quantifiers, rules of inference. Set operations, equivalence relations, injective, surjective and bijective functions, countable and uncountable sets, Russell's paradox, axiomatic systems.

Pigeonhole principle, mathematical induction, well-ordering principle. Permutations, combinations, binomial theorem, multisets, principle of inclusion and exclusion, discrete probability. Linear recurrence relations, complexity of algorithms, asymptotic growth of functions.

Graphs and digraphs, representation of graphs, isomorphism, paths and cycles, breadth-first and depth-first traversals, Eulerian and Hamiltonian circuits, graph colouring. Trees, binary trees, Huffman codes, Kraft's inequality, spanning trees, Kruskal's algorithm, Prim's algorithm. Finite state automata, Church-Turing thesis, Halting problem and undecidability, NP-hard and NP-complete problems.

TEXTBOOKS/REFERENCES

1. C. L. Liu, *Elements of Discrete Mathematics*, 2nd Edition, McGraw-Hill, 1985.
2. Kenneth H. Rosen, *Discrete Mathematics and its Applications*, 6th Edition, McGraw-Hill, 2006.
3. Norman L. Biggs, *Discrete Mathematics*, 2nd Edition, Oxford University Press, 2002.
4. J. P. Tremblay and R. Manohar, *Discrete Mathematical Structures with Applications to Computer Science*, McGraw-Hill, 1987.



## MAT 313: Abstract Algebra [3003]

Introduction to Group Theory: Groups, subgroups & homomorphisms, isomorphism theorems of Noether, cyclic groups, cosets and quotient groups, theorems of Lagrange & Cauchy, normal subgroups, group action on a set, symmetric & dihedral groups, direct products.

Advanced Group Theory: Sylow theorems, nilpotent and solvable groups, Jordan-Holder theorem.

Introduction to Ring Theory: Rings, ideals and homomorphisms, polynomial rings & formal power series, UFDs & Euclidean rings, PIDs, Gauss' theorem on UFDs, Eisenstein's criterion for irreducibility.

Introduction to Modules: Modules, homomorphisms & exact sequences, projective, injective and free modules, modules over a PID, fundamental Theorem of Abelian groups.

TEXTBOOKS/REFERENCES

1. Michael Artin, *Algebra*, Phi Learning Pvt. Ltd., New Delhi, 2011.
2. I.N. Herstein, *Topics in Algebra*, 2nd Edition, Wiley, 1975.
3. D.S. Dummit and R.M. Foote, *Abstract Algebra*, 3rd Edition, Wiley India, 2011.
4. J.B. Fraleigh, *A First Course in Abstract Algebra*, 7th Edition, Addison Wesley, 2002.
5. N.S. Gopalakrishnan, *University Algebra*, 2nd Edition, New Age International, 1986.
6. N. Jacobson, *Basic Algebra, Vol-1*, 2nd Edition, Freeman, 1985.

## MAT 314: Advanced Linear Algebra [3003]

Linear Algebra: Vector spaces, subspaces, quotient spaces, basis, change of basis, linear functional, dual space, projection, eigenvalues and eigenvectors, Cayley-Hamilton theorem, elementary canonical forms, annihilating polynomials, invariant subspaces, simultaneous triangulation, simultaneous diagonalization, direct sum decomposition, invariant direct sum, the primary decomposition theorem, Jordan form, inner product spaces, orthonormal basis, Gram-Schmidt process; adjoint operators, normal and unitary operators, self adjoint operators, spectral theorem for self

adjoint operators.

Numerical Linear Algebra: Linear systems; Gaussian elimination, iterative methods - Gauss-Jordan, Gauss-Seidel and successive over relaxation method; LU decomposition, positive definite system, Cholesky decomposition, condition numbers; orthogonal matrices, Householder transformation, Givens rotations, QR factorization, stability of QR factorization, singular value decomposition, sensitivity analysis of singular values and singular vectors, least square problems.

TEXTBOOKS/REFERENCES


1. K. Hoffman and R. Kunze, *Linear Algebra*, 2nd edition, Pearson Education, New Delhi, 2006.
2. I.N. Herstein, *Topics in Algebra*, 2nd Edition, Wiley and Sons, 1996.
3. L.N Trefethen and David Bau, *Numerical Linear Algebra*, SIAM , 1997.
4. G.H Golub and C.F Van Loan, *Matrix computations*, John Hopkins Univ Press, 1996.
5. D.S Watkins, *Fundamentals of Matrix Computations*, Wiley, 1991.
6. J.W. Dummel, *Applied Numerical Linear Algebra*, SIAM, 1997.
7. S. Axler, *Linear Algebra Done Right*, Springer, 1997.
8. C.D. Meyer, *Matrix Analysis and Applied Linear Algebra*, SIAM, 2001.


## MAT 315: Numerical Analysis [3003]

Roundoff errors and computer arithmetic, bisection method, fixed point iteration, Newton's method, Regula-Falsi method, error analysis for iterative methods, accelerating covergence, zeroes of polynomials and Muller's method. Interpolation and the Lagrange polynomial, divided differences, Hermite interpolation, cubic spline interpolation.

Numerical differentiation, Richardson's extrapolation, Newton-Cotes formulas, composite numerical integration, Romberg integration, adaptive quadrature, Gaussian quadrature, improper integrals.

Initial value problems (IVP) for ordinary differential equations: Euler's method, higher order Taylor methods, Runge-Kutta methods, multistep methods, error analysis, stability, solutions of stiff differential equations.



Boundary value problems (BVP): Finite difference method, collocation method, Galerkin method.

TEXTBOOKS/REFERENCES


1. R.L. Burden and J. D. Faires, *Numerical Analysis*, 7th Edn., Brookes/Cole, 2011.
2. Kendall E. Atkinson, *An Introduction to Numerical Analysis*, 2nd Edn., John Wiley, 1989.
3. F.B. Hildebrand, *Introduction to Numerical Analysis*, McGraw Hill, NewYork, 1974.
4. S.D. Conte and Carl de Boor, *Elementary Numerical Analysis - an algorithmic Approach*, 3rd Edn., McGraw Hill, 1980.
5. C.F. Gerald and P.O. Wheately, *Applied Numerical Analysis*, 5th Edn., Addison Wesley, 1994.


## MAT 321: Complex Analysis [3003]

PREREQUISITE

1. MAT 311-Real Analysis

Geometric representation of complex numbers, analytic functions: limits, derivatives, Cauchy-Riemann equations, sufficient conditions, Cauchy Riemann equations in polar form, harmonic conjugate.

Mapping by elementary functions: Linear functions, the function $1/z$, linear fractional transformations, the functions $w = z^n, w = e^z$, the logarithmic function and its branches, special fractional transformations.

Cauchy's theorem and Cauchy's integral formula for convex regions, Morera's Theorem, power series representation of analytic functions, zeros of analytic functions, open mapping theorem, maximum modulus theorem, Schwarz lemma, Weierstrass theorem on limits of analytic functions.

Laurent's theorem, classification of singularities, residue theorem, the principal part of a function, poles, quotient of analytic functions, evaluation of improper real integrals, improper integrals involving trigonometric functions, argument principle, Rouche's theorem.

Homology and homotopy versions of Cauchy's theorem, simply connected regions, normal families, Riemann mapping theorem.

TEXTBOOKS/REFERENCES

1. L.V. Ahlfors, *Complex Analysis*, Mcgraw-Hill, 1980.
2. R. Greene and S.G. Krantz, *Function Theory of One Complex Variable*, 3rd Edition, GSM, Vol. 40, AMS, 2006.
3. J. Bak and D.J. Newman, *Complex Analysis*, 3rd Edition, UTM, Springer, 2010.
4. J.W. Churchill and R.V. Brown, *Complex Analysis*, Mcgraw-Hill, 2009.
5. T.W. Gamelin, *Complex Analysis*, Springer-Verlag, 2001.
6. M.W. Wong, *Complex Analysis - Series on Analysis, Applications and Computation, Vol 2*, World Scientific, 2008.
7. J.H. Mathews and R.W. Howell, *Complex Analysis for Mathematics and Engineering*, Narosa, 2009.

## MAT 322: Measure Theory and Integration [3003]

PREREQUISITE

1. MAT 311-Real Analysis

Lebesgue measure: $\sigma$-algebras of sets, Borel sets, outer measure and its properties, $\sigma$-algebra of measurable sets, Lebesgue measure and its properties, a non-measurable set, measurable functions, Littlewood's three principles, Egoroff's theorem, Lusin's theorem.

Lebesgue integral: Simple functions, Lebesgue integral of a bounded function over a set of finite measure, bounded convergence theorem, Lebesgue integral of nonnegative functions, Fatou's Lemma, monotone convergence theorem, the general Lebesgue integral, Lebesgue convergence theorem.

Differentiation and integration: Differentiation of monotone functions, functions of bounded variation, differentiation of an integral, absolute continuity.

$L^p$-spaces: Definition and properties, Minkowski's inequality and Hölder's inequality, convergence and completeness of $L^p$, approximation in $L^p$, bounded linear functionals on $L^p$ spaces.



General measure and integration theory: Measure spaces, measurable functions, integration, general convergence theorems, signed measures, The Radon-Nikodym theorem, product measures - Fubini's theorem and Tonelli's theorem.

TEXTBOOKS/REFERENCES

1. H. L. Royden, *Real Analysis*, 3rd Edition, Phi Learning, 2009.
2. W. Rudin, *Real and Complex Analysis*, 3rd Edition, Mcgraw-Hill Education (India) Ltd, 2007.
3. E. M. Stein and R. Shakarchi, *Real Analysis: Measure Theory, Integration, and Hilbert Spaces*, Princeton University Press, 2005.
4. G. B. Folland, *Real Analysis: Modern Techniques and Their Applications*, 2nd Edition, John Wiley & Sons, 1999.
5. Paul R. Halmos, *Measure theory*, Springer, 2009.
6. G. Debarra, *Measure Theory and Integration*, New Age International, 1981.
7. Michael Taylor, *Measure Theory and Integration*, American Mathematical Society, 2006.
8. K. B. Athreya and S. N. Lahiri, *Measure Theory*, Hindustan Book Agency, 2006.
9. T. Tao, *An Introduction to Measure Theory*, GSM, Vol. 126, AMS, 2011.

## MAT 323: Galois Theory and Commutative Algebra [3003]

PREREQUISITE

1. MAT 313-Abstract Algebra

Field extensions, algebraic closure, splitting fields, separable and inseparable extensions, normal extensions, finite fields, quadratic residues and reciprocity, The Chevalley-Warning theorem, Galois extensions, fundamental Theorem of Galois theory, cyclic & cyclotomic extensions, solving equations by radicals, ruler & compass constructions, construction of regular polygons.

Noetherian rings & Noetherian modules, Hilbert's basis theorem, integral extensions, Hilbert zero theorem, localization, discrete valuation fields.

TEXTBOOKS/REFERENCES

1. Michael Artin, *Algebra*, Phi Learning Pvt. Ltd., New Delhi, 2011.
2. M.F. Atiyah and I.G. McDonald, *Introduction to Commutative Algebra*, Westview Press, 1994.

3. Balwant Singh, *Basic Commutative Algebra*, World Scientific, 2011.
4. D.S. Dummit and R.M. Foote, *Abstract Algebra*, 3rd Edition, Wiley India, 2011.
5. Thomas Hungerford, *Algebra*, Graduate Texts in Mathematics, Springer, 2005.

## MAT 324: Multivariate Analysis [3003]

PREREQUISITES

1. MAT 311-Real Analysis
2. MAT 314-Advanced Linear Algebra

Functions of several variables: Differentiation, directional derivatives, chain rule, rank theorem, inverse function theorem and Implicit function theorem.

Integration: Integration over a rectangle, surface and volume integrals, Fubini's theorem, change of variables formula, partitions of unity.

Curves: Definition of a curve, vector field, tangent vector field, unit-speed curve, energy of the curve, moving n-frame, Frenet-n-frame, the existence and uniqueness of a distinguished Frenet frame, Frenet equations, existence of curves with prescribed curvature functions, characterization of straight lines, characterization of the circle, rotation number, Umlaufsatz, normal representation for a space curve, curvature and torsion of a space curve, Frenet-Serret formula.

Smooth surfaces: Definition of a surface, vector field, tangent vector field, orientability, quadratic form, first fundamental form, invariance of the first fundamental form, second fundamental form, Weingarten map, third fundamental form, examples of surfaces.

Curves on smooth surfaces: definition, Meusnier's theorem, normal, principal, mean and Gauss curvatures, surfaces of constant mean curvature, Gauss map, geodesics.

TEXTBOOKS/REFERENCES

1. J.R. Munkres, *Analysis on Manifolds*, Westview Press, 1997.



2. Michael Spivak, *Calculus on Manifolds*, Westview Press, 1971.
3. C.C. Pugh, *Real Mathematical Analysis*, Springer, 2010.
4. M. Spivak, *A Comprehensive Introduction to Differential Geometry, Vol. 1*, Publish or Perish, Boston, 1970.
5. M.P. do Carmo, *Differential Geometry of Curves and Surfaces*, Prentice-Hall, Engelwood, NJ, 1976.

## MAT 325: General Topology [3003]

PREREQUISITE

1. MAT 311-Real Analysis

Topological Spaces and Continuous Functions: Topological spaces, Basis for a topology, The order topology, The product topology, The subspace topology, Closed sets and limit points, Continuous functions, The metric topology, The quotient topology.

Connectedness and Compactness: Connected spaces, connected sets in the real line, Components and path components, Local Connectedness, Compact spaces, Compact sets in the real line, Limit point compactness, Local compactness.

Countability and Separation Axioms: The countability axioms, The separation axioms, The Urysohn lemma, The Urysohn metrization theorem.

The Tychonoff theorem, Completely regular spaces, The Stone-Cech compactification, Paracompactness.

TEXTBOOKS/REFERENCES

1. J.R. Munkres, *Topology*, 2nd Edition, Prentice Hall, 2000.
2. G. F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963.
3. J. Dugundji, *Topology*, Prentice Hall, 1965.
4. I.M. Singer and J.A. Thorpe, *Lecture Notes on Elementary Topology and Geometry*, Springer, 1976.

## MAT 411: Functional Analysis [3003]

PREREQUISITES

1. MAT 321-Complex Analysis
2. MAT 322-Measure Theory and Integration

Normed linear spaces, Riesz lemma, characterization of finite dimensional spaces, Banach spaces. Operator norm, continuity and boundedness of linear maps on a normed linear space.

Fundamental theorems: Hahn-Banach theorems, uniform boundedness principle, divergence of Fourier series, closed graph theorem, open mapping theorem and some applications.

Dual spaces and adjoint of an operator: Duals of classical spaces, weak and weak* convergence, adjoint of an operator.

Hilbert spaces: Inner product spaces, orthonormal set, Gram-Schmidt ortho-normalization, Bessel's inequality, orthonormal basis, separable Hilbert spaces. Projection and Riesz representation theorems: Orthonormal complements, orthogonal projections, projection theorem, Riesz representation theorem.

Bounded operators on Hilbert spaces: Adjoint, normal, unitary, self-adjoint operators, compact operators. Unbounded operators.

Spectral theorem: Spectral theorem for compact self adjoint operators, statement of spectral theorem for bounded self adjoint operators.

TEXTBOOKS/REFERENCES

1. Martin Schechter, *Principles of Functional Analysis*, AMS (Indian Edition, Uni. Press), 2009.
2. Peter D. Lax, *Functional Analysis*, Wiley-Inter Science, 2002.
3. M. Reed and B. Simon, *Functional Analysis (Methods of Modern Mathematical Physics - Volume 1)*, Academic Press, 1981.
4. Y. Eidelman, V. Milman and A. Tsolomitis, *Functional Analysis: An Introduction*, GSM, Vol. 66, AMS, 2004.
5. Tosio Kato, *Perturbation Theory for Linear Operators*, Springer, 1995.
6. G.F. Simmons, *Introduction to Topology and Modern Analysis*, Mc-Graw Hill, 1963.
7. B. Bollabas, *Linear Analysis*, Cambridge University Press (Indian Edition), 1999.



8. E. Kreyeszig, *Introduction to Functional Analysis with Applications*, Wiley, 1989.
9. W. Rudin, *Functional Analysis*, 2nd Edition, Tata McGraw Hill, 2006.

## MAT 412: Probability Theory and Random Processes [3003]

PREREQUISITE

1. MAT 322-Measure Theory and Integration

Review of measure theory: measure spaces, Lebesgue measure, integration, transformations, product spaces, distributions and expectations.

Weak convergence: characteristic functions, moment generating functions, weak convergence.

Sum of independent random variables: independence and convolution, Khintchine's weak law of large numbers, strong limit theorems, series of independent random variables, Kolmogorov's strong law of large numbers.

The central limit theorems: tight families of probability distributions, Prokhorov's theorem, Skorohod's theorem, compact support functions, the central limit theorem, stable laws, infinitely divisible distributions, Khintchine's law of iterated logarithm.

Dependent random variables: conditioning, conditional expectation and conditional probability, Markov chains, stopping times and renewal times.

Martingales: filtration and semi martingales, martingale convergence theorems, Doob decomposition theorem, stopping times, application to random walks, Markov chains.

TEXTBOOKS/REFERENCES

1. S.R.S. Varadhan, *Probability Theory*, Courant Institute of Mathematical Sciences, 2001.
2. Rick Durrett, *Probability: Theory and Examples*, 4th Edition, Cambridge University Press, 2010.

3. D.W. Stroock, *Probability Theory, An Analytic View*, 2nd Edition, Cambridge University Press, 2010.
4. A. N. Shiryaev, *Probability*, 2nd Edition, Springer, 1995.
5. Jean Jacod and Philip Protter, *Probability Essentials*, 2nd Edition, Springer, 2004.
6. Leo Breiman, *Probability*, Society for Industrial and Applied Mathematics, 1992.
7. P. Billingsley, *Probability and Measure*, 3rd Edition, Wiley (India), 2008.
8. O. Kallenberg, *Foundations of Modern Probability*, 2nd Edition, Springer, 2010.
9. K.R. Parthasarathy, *Introduction to Probability and Measure*, Hindustan Book Agency, 2005.

## MAT 413: Number Theory and Cryptography [3003]

Divisibility, Euclid's algorithm, prime numbers, fundamental theorem of arithmetic, prime number theorem, Bertrand's postulate. Congruences, complete and reduced residue systems, Chinese remainder theorem, Wilson's theorem, Fermat's little theorem, pseudoprimes, Euler's theorem, primitive roots. Quadratic residues, Legendre symbol, law of quadratic reciprocity, Jacobi symbol, binary quadratic forms.

Arithmetic functions, Euler's totient function, perfect numbers, Mobius inversion formula. Linear diophantine equations, Pythagorean triples, Fermat's Last Theorem, Lagrange's theorem, Waring's problem, Hardy-Littlewood circle method. Irrationality of $e$ and $\pi$, continued fractions, best approximations, quadratic irrationals, Pell's equation.

Classical cryptography, block ciphers, public key cryptography, RSA cryptosystem, discrete logarithm problem, Diffie-Hellman key exchange, Elliptic curve cryptosystems, zero knowledge protocols. Algorithms for primality testing, Fermat's factorisation, Pollard's rho method, quadratic sieve.

TEXTBOOKS/REFERENCES

1. I. Niven, H. S. Zuckerman and H. L. Montgomery, *An Introduction to the Theory of Numbers*, 5th Edition, Wiley, 1991.
2. Neal Koblitz, *A Course in Number Theory and Cryptography*, 2nd Edition, Springer, 1994.
3. G. H. Hardy and E. M. Wright, *An Introduction to the Theory of Numbers*, 6th Edition, Oxford University Press, 2008.



4. Kenneth Ireland and Michael Rosen, *A Classical Introduction to Modern Number Theory*, 2nd Edition, Springer, 1990.
5. James K. Strayer, *Elementary Number Theory*, Waveland Press, 2001.

## MAT 414: Theory of Ordinary Differential Equations [3003]

PREREQUISITE

1. MAT 311-Real Analysis

Review of various solving techniques: integrating factor method, separation of variables, variation of parameters, method of undetermined coefficients.

Existence and uniqueness of initial value problems: Picard-Lindelöf theorem, Peano's existence theorem, Cauchy-Peano existence theorem, Gronwall's inequality, maximal and minimal solutions, right derivates, differential inequalities, uniqueness theorems, dependence on initial conditions and parameters.

Linear systems: existence and uniqueness of solutions of systems, general properties of linear systems, fundamental matrix solution, systems with constant coefficients, periodic linear systems, asymptotic behaviour of solutions of linear systems.

Stability theory: stability of quasi-linear systems, two-dimensional autonomous systems, limit cycles and periodic solutions, Poincaré-Bendixson theory in two-dimension, Lyapunov's direct method for autonomous and non-autonomous systems.

Boundary value problems: Linear BVP, Green's function, maximum principles, Sturm-Liouville theory, eigenfunction expansion.

TEXTBOOKS/REFERENCES

1. Philip Hartman, *Ordinary Differential Equations*, 2nd Edn., SIAM, 2002.
2. E.A. Coddington and N. Levinson, *Theory of Ordinary Differential Equations*, McGraw-Hill, 1984.
3. Lawrence Perko, *Differential Equations and Dynamical Systems*, 3rd Edn., Springer, 2006.
4. Ravi P. Agarwal and Donal O'Regan, *An Introduction to Ordinary Differential Equations*, Springer, 2008.

5. G.F. Simmons, *Differential Equations with Applications and Historical Notes*, 2nd Edn., McGraw-Hill, 1991.
6. Hirsch and Smale, *Differential Equations, Dynamical Systems and Linear Algebra*, Academic Press, 1974.
7. Ivar Stakgold, *Green's Functions and Boundary Value Problems*, Wiley, New York, 1979.
8. G. Birkhoff and G-C Rota, *Ordinary Differential Equations*, 4th Edn., Wiley, 2004.



## Partial List of Electives

1. Functional Analysis
2. Partial Differential Equations
3. Combinatorics and Graph Theory
4. Differential Geometry
5. Algebraic Geometry
6. Algebraic Number Theory
7. Algebraic Topology
8. Rings and Modules
9. Lie Groups and Lie Algebras
10. Representation Theory
11. Nonnegative Matrices and Applications
12. Advanced Combinatorics
13. Diophantine Approximations
14. Harmonic Analysis
15. Operator Theory
16. Advanced Partial Differential Equations
17. Stochastic Analysis
18. Control Theory
19. Mathematical Finance
20. Mathematical Fluid Dynamics
21. Calculus of Variations
22. Operations Research
23. Programming and Data Structures
24. Finite Element Methods

# School of Physics

## Theory Courses

### PHY 311 Mathematical Methods in Physics [3003]

Calculus of Variations: Equations of mathematical physics as variational problems, Lagrange multipliers, origin of eigenproblems; Ordinary differential equations: Linear equations: Solution space, linear independence, Wronskians. Eigenvalue problems: Boundary conditions, self-adjointness, completeness of eigen functions, Fourier series, continuous spectra and Fourier integrals. Green Functions.

Partial Differential equations: Classification of PDE's. Hyperbolic equations: wave equation, method of characteristics, shocks and weak solutions. Heat equation: solution by integral transforms. Elliptic equations: Dirichlet and Neumann problems, Poisson's equation, Legendre functions, spherical harmonics, Bessel and spherical Bessel functions, examples from electrostatics.

Complex Analysis: Complex differentiability. Conformal mapping and its physical applications. Cauchy, Taylor, and Laurent theorems, analytic functions. Applications to contour integration, solution of differential equations and asymptotics. Integral Equations: Solution via Fourier and Laplace transforms, Abel's equation.

Textbooks/References


1. G. B. Arfken and H. J. Weber, *Mathematical methods for physicists*, Academic press.
2. R. Courant and Hilbert, *Methods of mathematical physics*, Wiley.
3. Dennery and Andre Krzywicki, *Mathematics for Physicists*, Dover.


### PHY 312 Classical Mechanics [3003]

Review of Newtonian mechanics, Generalized coordinates, The principle of least action, Lagrange's equation, The Lagrangian for a free particle and for a system of particles;Symmetries, Conservation laws and Noethers theorem, Conservation of energy, momentum and angular momentum; Integrating the equations of motion: motion in one dimension, Central force

motion and Kepler's problem, Collisions: elastic collisions, scattering and Rutherfords formula.

Motion of a rigid body, Angular velocity, Moment of inertia, Angular momentum, Euler angles, Euler's equations. Motion in a non-inertial frame; Small oscillations: simple harmonic, forced, damped and anharmonic oscillations; The Hamilton equations of motion, Legendre transformations, Cyclic coordinates, Routhian; Invariance properties of the Lagrangian and Hamiltonian descriptions, Poisson and Lagrange brackets, Canonical transformations, Group properties and methods of constructing canonical transformations; Hamilton-Jacobi theory and action-angle variables, The harmonic oscillator as an example, The Kepler problem in action angle variables.

TEXTBOOKS/REFERENCES

1. H. Goldstein, C. Poole and J. Safko, *Classical Mechanics*, 3rd Ed. Addison-Wesley, 2005.
2. L. D. Landau and E. M. Lifshitz, *Mechanics*, Vol. 1 of course of Theoretical Physics, Pergamon Press, 2000.

## PHY 313 ELECTRONICS - 1 [3003]

Basic concepts of semiconductors, conduction and doping, PN junction, diode characteristics, forward bias, reverse bias, static and dynamic resistance, junction capacitance, Diode approximations, equivalent circuit, Zener and avalanche breakdown, Heterojunction;

Thevenins and Nortons theorems, Voltage and current source; Diode circuits — Rectifiers – half wave and full wave – efficiency and ripple factor, Voltage multiplier, clipper and clamper circuits.

Filters Capacitor, RC and LC filters; Special purpose diodes – Zener, Schottky diode, Varactor, Tunnel diode; Bipolar Junction transistor, the transistor action, transistor current components, Modes of operation, common-base, common emitter and common collector configurations, Current-voltage characteristics of CB, CE, CC configuration, current gain , and . Early effect, DC load line, Q-point, saturation and cut-off regions; Transistor biasing - Base bias, Emitter bias, Transistor switch, Voltage divider bias, Self bias, Collector feedback bias. Stability factor.



AC Models - ac resistance of the emitter diode, ac input impedance, ac load-line, ac-equivalent circuits — T- model, $\Pi$-model, Transistor hybrid model — determination of h-parameters from characteristics, analysis of a transistor amplifier using h-parameters, comparison of amplifier configurations, simplified h-model; Voltage amplifiers – voltage gain, DC, RC, transformer coupled amplifiers, frequency response of RC coupled amplifiers, cascading CE & CC amplifiers, Darlington pair. positive and negative feedback-advantages of negative feedback-input and output resistances-voltage series and current series feedback-frequency response of amplifiers with and without feedback.

Power amplifiers — Class A, Class B, Class C amplifiers, Push pull amplifiers; Oscillators, Wien bridge oscillator, Colpitts oscillator, phase shift oscillator, resonant circuit oscillators, crystal oscillator, square wave and triangle wave generators, Schmitt trigger, 555, multivibrators.

TEXTBOOKS/REFERENCES

1. A. Malvino and D. J. Bates, *Electronic principles*, Mcgraw-hill, 2006.
2. J. Millman, C. C. Halkias and S. Jit, *Electronic devices and circuits*, Tata Macgraw Hill, 2007.
3. S. M. Sze, *Semiconductor Devices, Physics and Technology* (2nd Ed.), Wiley India, 2008.
4. T. L. Floyd and R. P. Jain, *Digital Fundamentals* (8th Ed.), Pearson Education, 2005.
5. M. Morris Mano and M. D. Ciletty, Digital Design (4th Ed.), Pearson Education, 2008.
6. R. S. Gaonkar, *Microprocessor architecture, programming, and applications with 8085*, Prentice Hall, 2002.

## PHY 314 QUANTUM MECHANICS - 1 [3003]

Quantum kinematics: The state vector, Dirac Bra and Ket notation, the principle of superposition, the Stern-Gerlach experiment. Hilbert space and some general properties of linear vector spaces, Rays and vectors in Hilbert space, Normalization, Basis vectors. Non commutating operators and observables, the uncertainty principle, Operators, eigenvalues, eigenvectors, observables and expectation values (a bit of linear algebra), Quantum amplitudes, probabilities and the Born rule. A basis labeled by a

continuous parameter and the wave function, The position and momentum bases, Fourier transforms, Delta function normalization, Function spaces, The uncertainty principle revisited, The probability current and the continuity equation.

Quantum Dynamics: The Schrödinger equation, The Hamiltonian and the idea of generators, finite time evolution and unitary transformations, properties of unitary transformations, time evolution of expectation values. The Heisenberg picture, Commutation relations; The time independent Schrödinger equation, Stationary states, Stationary states, Examples: particle in an infinite square well and particle in a finite square well, scattering off a potential barrier. quantum tunneling, the quantum harmonic oscillator.

The Schrödinger equation in three dimensions: The Schrödinger equation in spherical coordinates, Separation of variables, The radial equation and energy quantization, the angular equation, spherical harmonics and introduction to quantized angular momentum. Spin, The Hydrogen atom; Charged Particle in a Magnetic Field: Oscillator algebra; Energy spectrum and Eigenstates; Landau levels, Wave functions.

TEXTBOOKS/REFERENCES

1. J. S. Townsend, *A modern approach to quantum mechanics*, University Science Books (2000)
2. J. J. Sakurai, *Modern quantum mechanics*, Addison-Wesley, 1994.
3. R. Shankar, *Principles of quantum mechanics*, Plenum Publishers, 1994.
4. R. P. Feynman, *The Feynman lectures on physics Vol 3*, Narosa (2007)
5. Marvin Chester, *Primer of Quantum Mechanics*, Dover Publications (2003)

## PHY 321 STATISTICAL MECHANICS [3003]

Review of thermodynamics and Probability theory: The Laws of Thermodynamics. Interactions – The Conditions for Equilibrium, Thermal Interaction – Temperature, Volume change – Pressure, Particle interchange – chemical potential. Random variable, Distribution function, Central limit theorem; Statistical Picture of Mechanics: Statistical description of a classical particle, Dynamics in Phase space, Ergodicity, Stationary states and Liouville theorem, Microcanonical and Canonical states.



Methadology of Statistical Mechanics: Definition of counting and partition function – Density of states, Classical Partition function, Examples – Two level system, Harmonic oscillator, Particle in a 1D and 3D box. Equipartition theorem, Virial theorem; Thermodynamic Averages: The Partition Function, Generalised Expression for Entropy Gibbs entropy, Free Energy and Thermodynamic Variables, The Grand Partition Function , Grand Potential and Thermodynamic variables, Examples of non-interacting systems – Einstein and Debye model, Ideal Paramagnet (negative temperature).

Quantum Distributions: Bosons and Fermions, Grand Potential for Identical Particles, The Fermi and Bose Distribution, The Classical Limit The Maxwell Distribution, Examples: Black-body radiation, Bose Einsten Condensation and Fermi gas at low temperatures. Weakly interacting Systems: Cluster Expansion, Van der Waal's gases; Phase transitions - Phenomenology: Phase diagrams, Symmetry, Order of phase transitions and Order parameter, Conserved and non-conserved order parameters, Critical exponents, Scaling theory and scaling of free energy.

Strongly interacting systems: Phase transitions — Introduction to the Ising model, Magnetic case, lattice gas and phase separation in alloys and Bragg-Williams approximation. Transfer matrix method in 1D. Landau theory, Symmetry breaking, Distinction between second order and first order transitions, Discussion of ferroelectrics. Broken symmetry, Goldstone bosons, fluctuations, scattering, Ornstein Zernike, soft modes.

TEXTBOOKS/REFERENCES

1. F. Reif, *Statistical Physics: Berkeley Physics Course Vol. 5*, Tata Mcgraw-hill, 2011.
2. F. Mandl, *Statistical Physics* (2nd Ed.), John Wiley & Sons, 1991.
3. H. B. Callen, *Thermodynamics and an Introduction To Thermostatistics*, Wiley, 2006.
4. R. K. Pathria, *Statistical Mechanics* (2nd Ed.), Elsevier, 2002.

## PHY 322 CONDENSED MATTER PHYSICS - 1 [3003]

Crystal structure: Bravais lattice, two and three dimensional lattices, primitive cells, symmetry, space group and point groups, classification of

lattices by symmetry; Experimental determination of crystal structure: Scattering from crystals, Laue method, rotating crystal method, powder method, interaction of X-rays with matter, deciphering the structure; Electronic structure: The single electron model, free electron model, specific heat of noninteracting electrons; The Schrödinger equation and symmetry: Blochs theorem, Fermi surface, density of levels, van Hove singularities, Kronig-Penny model, band structure, rotational symmetry and group representations.

Models: Nearly free electrons, Brillouin zones, tightly bound electrons,Wannier functions, tight binding model, electron-electron interactions, Hartree-Fock equations, density functional theory; Mechanical properties: elasticity, liquid crystals, phonons, Einstein and Debye models, inelastic scattering from phonons; Electron transport: Drude theory, semiclassical electron dynamics, noninteracting electrons in an electric field, Zener tunneling.

TEXTBOOKS/REFERENCES

1. Michael P. Marder, *Condensed matter physics*, John Wiley, 2000.
2. N. W. Ashcroft, N. David Mermin, *Solid state physics*, Harcourt, 1976.
3. C. Kittel, *Introduction to solid state physics*, 7$^{th}$ edition, John Wiley, 2004.
4. A. J. Dekker, *Solid state physics*, Macmillan India , 2005.

## PHY 323 ELECTRONICS 2 [3003]

FETS, characteristics, small signal model, common source and common drain amplifiers, biasing; MOSFET. Silicon controlled rectifiers, SCS, Diac, Triac, characteristics and applications; Operational amplifiers — actual circuits of operational amplifiers, uses as amplifiers, analog circuits adding, integration and differential circuits, comparators, waveform generators, logarithmic generators.

Digital Electronics: Binary number systems, binary-decimal conversions, hexadecimal and Octal numbers, BCD, Gray code, ASCII code; Boolean algebra, Laws of Boolean algebra, De Morgans theorem, Simplification of Boolean expressions, Karnaugh Map; Logic gates, combinational logic circuits, deriving the truth table, designing combinational logic from truth table. NAND and NOR gates; Half adder, full adder, look-ahead-carry implementation, Magnitude comparators, decoders, encoders multiplexers, demultiplexers.



Flip-flops — RS, D, JK flip-flops, multivibrators. Synchronous and asynchronous counters, counter applications, Shift registers, different types, shift register applications, D/A and A/D conversions; Memories – ROM, PROM and EPROM, RAM, special memories and applications. Integrated circuits, CMOS, PMOS and NMOS; Microprocessors architecture, addressing modes, 8085, 8086 microprocessors, peripheral devices, microcontrollers.

TEXTBOOKS/REFERENCES

1. A. Malvino and D. J. Bates, *Electronic principles*, Mcgraw-hill, 2006.
2. J. Millman, C. C. Halkias and S. Jit, *Electronic devices and circuits*, Tata Macgraw Hill, 2007.
3. J. Millman, and C. C. Halkias, *Integrated electronics*, Tata Macgraw Hill, 2008.
4. S. M. Sze, *Semiconductor Devices, Physics and Technology* (2$^{nd}$ Ed.), Wiley India, 2008.
5. T. L. Floyd and R. P. Jain, *Digital Fundamentals* (8$^{th}$ Ed.), Pearson Education, 2005.
6. M. Morris Mano and M. D. Ciletty, Digital Design (4$^{th}$ Ed.), Pearson Education, 2008.
7. R. S. Gaonkar, *Microprocessor architecture, programming, and applications with 8085*, Prentice Hall, 2002.

## PHY 324 ELECTRODYNAMICS AND SPECIAL THEORY OF RELATIVITY [3003]

Review of Maxwell's equations and basic electrodynamics.

Postulates of the special theory of relativity, Experimental evidence, An inertial observer, Space-time diagrams, Coordinates used by another observer, Invariance of the interval, Invariant hyperbolae, The Lorentz transformation, The velocity composition law, Four vectors: four velocity and four momentum;Principle of least action, Energy and momentum, Transformation of distribution functions, Elastic collisions, Angular momentum.

Charges in electromagnetic fields: Elementary particles in special theory of relativity, four potential of a field, Gauge invariance, Electromagnetic field tensor, Lorentz transformation of the field, Invariants of the field.

Electromagnetic field equations: The action function of the electromag-

netic field and the first pair of Maxwell's equations, Four dimensional current vector, Continuity equation, The second pair of Maxwells equations, Energy density and energy flux, the energy-momentum tensor of the electromagnetic field.

Constant electromagnetic fields: Coulombs law, Electrostatic energy of charges, The field of a uniformly moving charge, Motion in the coulomb field, The dipole and multipole moments, System of charges in an electric field, Magnetic field and moments. Larmors theorem.

Electromagnetic waves: The wave equation, Plane waves, Spectral resolution, Partially polarized light, Fourier resolution of the electrostatic field. Retarded and advanced potentials. Lienard-Wiechert potentials.

TEXTBOOKS/REFERENCES

1. L. D. Landau and E. M. Lifshitz, *Classical Theory of Fields*, Vol-2 of course of theoretical physics, Pergamon, 2000.
2. David J. Griffiths, *Introduction to Electrodynamics*, Prentice Hall, 1999.
3. Bernard F. Schutz, *A first course in General Relativity*, Cambridge, 2009.
4. John David Jackson, *Classical Electrodynamics*, John Wiley, 1998.

## PHY 411 EXPERIMENTAL METHODS [3003]

Electrical characterization techniques: Resistance measurement, various configurations (2/4 probe, van der pauw). AC/DC techniques range of application. Voltage and current sourcing techniques, source-meter and sample impedance matching; Low current measurement, leakage current; AC measurement techniques, lock-in amplifiers — operating principle (phase locking); AC + DC mixing and application in directly obtaining various harmonics of the primary signal; Application of above in designing and measuring the R vs T or constant current V vs T curve of a diode. Fitting the bare data by linearization technique, obtaining best fit; Introduce calibration curve of a sensor and its predictive value.

Vacuum Techniques: Introduction to the concept of low pressure with examples and measurement scales; Production and measurement of high and ultra high vacuum. Various pumping methods (rotary/diffusion/turbo molecular/ion/cryo pump) and their area of application; Design of a vacuum chamber, pumping impedance and pumping speed; Comparison of different gauges used in measurement (pirani/penning/ion/capacitance)



operating principles and ranges of application; Working principle of a residual gas analyser; Vapour pressure and choice of materials in a vacuum system.

Cryogenics: Introduction to low and high temperature applications and its importance; Relevant temperature ranges vis--vis practical applications (examples from real systems). Temperature scales vs energy scales in physical systems; Room temperature – mK range (300 – 77K, 77 – 4.2K, 4.2 – 1.6K, $< 1.6K$); Production and Measurement: Introduction to cryogens (liquid nitrogen, helium), pumping on cryogens. Types of thermometers comparative study and application ranges and conditions (Pt100, diode, cernox, capacitance, carbon, thermocouple). T measurement in high magnetic field and low temperatures ($< 1.6K > 5T$). Introduction to attaining high magnetic field in lab. Piecewise curve fitting for a cernox thermometer. Temperature control, negative feedback and zeroing of a PID controller. (Electrical and thermal properties of common materials at low T. Cu, Al, Pt, Si, Rubber, Silicone, PTFE, Sapphire, Carbon, Glass, Macor, Paper via a comparison chart or graph will be helpful).

Sample deposition Techniques: Thermal, electron beam, Knudsen Cell, RF/DC sputtering – applications and limitations. Thickness monitor, profilometer etc.Characterization techniques: Principle of pulse NMR, measurements of NMR spectra, spin-lattice relaxation time (T1) and spin-spin relaxation time (T2); Basic principles of Electron Spin Resonance (ESR) and its application; Magnetic measurement, principle of Vibrating Sample Magnetometer (VSM) and SQUID magnetometer; Measurement of heat capacities.

TEXTBOOKS/REFERENCES

1. Charles P. Slichter, *Principles of Magnetic Resonance*, Springer, 1989.
2. E. Fukushima, *Experimental Pulse NMR: A Nuts And Bolts Approach*, Westview Press, 1993.

## PHY 412 CONDENSED MATTER PHYSICS - 2 [3003]

PREREQUISITE

1. PHY 322: Condensed Matter Physics - 1

Semiconductors: intrinsic and extrinsic semiconductors, hole, effective mass, laws of mass action, electron and hole mobilities, impurity band

conduction , p-n junction , Shottky barrier , quantum Hall effect ; Crystal defects: Schottky vacancies, Frenkel defects, F-center etc; Optical Processes: Optical reflectance, Kramers-Kronig relations, Electronic interband transitions, Frenkel excitons, Mott-Wannier excitons, Raman effect in crystals etc.

Magnetism: dia-, para-magnetism, Curie-Weiss law, Van-Vleck and Pauli paramagnetism, ferro-, anti- and ferrimagnetism. Classical and quantum theories, Hunds rule, Exchange interaction, Heisenberg model, mean field theory, spin wave.

Superconductivity: Experimental survey, Thermodynamics of superconductors, Meissner effect, Londons equation, BCS theory, Ginzburg-Landau theory, flux quantization, coherence length, Type-I and Type-II superconductors, Superconducting tunneling, DC and AC Josephson effects, SQUIDs, High-T superconductivity: structure and transport properties.

Dielectric and Ferroelectrics: General concept, dielectric constant and polarizability, Structural phase transitions, Ferroelectric crystals, Displacive transitions: Soft phonon modes, Landau theory of the phase transition, first and second order phase transitions, Ferroelectric domains, Piezoelectricity, and Ferroelasticity; Magnetic resonance.

TEXTBOOKS/REFERENCES

1. Michael P. Marder, *Condensed matter physics*, John Wiley, 2000.
2. N. W. Ashcroft, N. David Mermin, *Solid state physics*, Harcourt, 1976.
3. C. Kittel, *Introduction to solid state physics*, 7$^{th}$ edition, John Wiley, 2004.
4. A. J. Dekker, *Solid state physics*, Macmillan India, 2005.

### PHY 413 QUANTUM MECHANICS - 2 [3003]

PREREQUISITES

1. PHY 314: Quantum Mechanics - 1
2. PHY 312: Classical Mechanics

Angular Momentum: Angular Momentum algebra; Eigenvalues and Eigenstates of Angular Momentum; SU(2) Representations; Addition of Angular Momentum; Schwinger's Oscillator Model of angular momentum; Motion in Central Potential, Spherical waves, Resolution of a plane wave, Asymptotic properties of Radial wave-functions, Coulomb potential, Accidental degeneracy.



Approximation methods: Time-independent Perturbation Theory (non-degenerate case, degenerate case), and Applications (Fine structure of hydrogen, relativistic and spin-orbital effects, Zeeman effect, Stark effect, Van der Waals interaction); Variational Methods and Applications (Ground and Excited states of Helium). Semi-classical (WKB) Approximation and Applications (Bohr-Sommerfeld quantization rule, Tunneling, Transition Probabilities, Bound-state energies etc).

Time-dependent Potentials and the Interaction Picture: Time-dependent Perturbation Theory, Applications to Interactions with the Classical Radiation Field, Fermi's Golden rule; Transition rates, Spontaneous emission, Energy Shift and Decay Width. The Adiabatic Approximation and Geometrical Phase: Adiabatic theorem, Berry's phase, Application to spin in a time-varying Magnetic Field, Born-Oppenheimer approximation.

Identical particles, Permutation Symmetry, Symmetrization Postulate, Two electron system, The Helium Atom, Permutation symmetry and Young Tableau.

Scattering theory: Scattering cross-section; Lippmann-Schwinger Equation; Born Approximation and application to scattering from various spherically symmetric potentials, including Yukawa and Coulomb; Optical theorem; Eikonal approximation; Free-Particle states (plane waves, spherical waves); Method of Partial Waves; Low-Energy Scattering and Bound States; Resonance Scattering; Identical Particles and Scattering; Symmetry considerations in Scattering; Time-dependent formulation of Scattering; Inelastic Electron-Atom Scattering.

TEXTBOOKS/REFERENCES

1. J. J. Sakurai, *Modern quantum mechanics*, Addison-Wesley, 1994.
2. R. Shankar, *Principles of quantum mechanics*, Plenum Publishers, 1994.
3. Cohen-Tannoudji and Diu-Laloë, *Quantum Mechanics* (2 volumes), Wiley, 2000.
4. L. D. Landau and E. M. Liftshitz, *Quantum Mechanics* Vol-3 of course of theoretical physics, Butterworth-Heinmann, 2000.

## List of Electives in Physics

1. High Energy Physics
2. Atomic and Molecular Physics

3. Computational Techniques and Programming Languages
4. Fluid dynamics
5. Nonlinear dynamics
6. Advanced quantum mechanics: many body theory
7. Statistical field theory
8. Non-equilibrium statistical mechanics
9. Advanced mathematical methods
10. Early universe
11. Astrophysics
12. Quantum information theory
13. Physics at the nano scale
14. Quantum theory of fields
15. General theory of relativity and cosmology
16. String theory

## Laboratory Courses

### PHY 315 Advanced Physics Experiments I [0093]

1. Viscosity of a Liquid - Oscillating Disc Method
2. Viscosity of Liquid Variable or Constant Pressure Head.
3. Torsion Pendulum Rigidity modulus of material of wire
4. Young's Modulus: Cornu's Method (Elliptical & Hyperbolic Fringes)
5. Spectrometer: $i - i'$ curve
6. Spectrometer Hartmann's formula (Find unknown wavelength)
7. Youngs modulus Optic Lever Mehtod
8. Surface Tension Capillary Rise (Water) Method, Capillary Dip (Mercury) Method and Quincke's Method (Mercury)
9. Beam Profile of Laser Divergance of Laser Beam
10. Diffraction by ultrasonic waves Velocity of Sound in Liquid
11. $e/m$ - Thomsons Method
12. Dipole Moment of Organic Molecule
13. Fabrey-Perot Interferometer
14. Michelson's Interferometer
15. LCR circuit (Series and Parallel) Frequency Response and Value of Unknown L
16. AC Bridges Anderson, Maxwell, DeSauty, Owen



17. Photo-diode Characteristics (Intensity vs. Photo current, dark resistance of photo diode)
18. Transistor Characteristics (CE)
19. Transistor as a Switch and Amplifier
20. Voltage Controlled Oscillator (Transistor): Variation in frequency with control voltage
21. Voltage Controlled Oscillator (555 timer): Variation in frequency with control voltage
22. Colpit & Hartley Oscillators (Transistor)
23. Phase-shift & Wein-bridge Oscillators (Transistor)
24. Mono-stable Multivibrator (Transistor)
25. Bi-stable Multivibrator (Transistor)

### PHY 325 Advanced Physics Experiments II [0093]

1. Velocity of light Foucolt's Method
2. Photo-electric Effect Characteristics of photoelectric emission (I-V for different wave lengths and different frequencies), Plancks Constant from Voltage-frequency curve
3. Thermal diffusivity of brass
4. Arc Spectrum Iron or Brass
5. Absorption Spectrum $KMnO_4$ or Iodine
6. Calibration of Secondary Thermometers
7. Thermal Relaxation of Bulb
8. X-ray spectrum analysis
9. Resistivity (4 probe Method) & Temp. Coefficient of Resistance of Copper
10. FET Characteristics and Amplifier using FET
11. SCR, Triac, Diac Characteristics
12. Op-Amp Inverting and Non-inverting amplifiers (Frequency Response)
13. Op-Amp Mathematical Tools (Addition, Integration, Differentiation)
14. Square, Triangular & Saw-tooth wave generators using Op-amp
15. Low-pass Signal Filter (First and Second Order) Frequency Response
16. High-pass Signal Filter (First and Second Order) Frequency Response
17. Band Pass and Band Reject Filters Frequency Response
18. Differential Amplifier using transistor CMRR, Frequency responses (Common and Diff. Modes)

19. Amplitude modulation Modulation index for different amplitudes of audio signal.
20. SR & JK Flip-flops
21. Decade Counters with seven segment Display
22. D/A Converter
23. Microprocessor programming Multiplication / Bubble sorting
24. Microprocessor programming - A/D Converter
25. Microprocessor programming - Stepper Motor

### PHY 415 Advanced Physics Experiments III [0093]

1. Curie-Wiess Law of Dielectric Material
2. Zeeman Effect To verify the ratio of $_0/hc$ using Zeeman splitting in $6\,^3P_2$ and $7\,^3S_1$ states of mercury.
3. Nuclear Magnetic Resonance
4. Hall Effect
5. ESR spectrometer: $g$-factor of a sample
6. Band gap of a semiconductor
7. Magnetic susceptibility - Quincke's Method
8. $B - H$ Curve (Ferromagnet)
9. Noise fundamentals
10. Optical Pumping
11. Two slit Interference - one photon at a time
12. Damped-Driven Pendulum
13. GM Counter
14. Fiber Optics
15. Super Conductivity
16. Design new experiments (micro projects)

# Faculty

## School of Biology

| Faculty members | Research interests | Contact details[1] |
|---|---|---|
| Manna, Tapas<br>Assistant Professor | Biochemistry<br>Mammalian Cell Biology | tmanna@<br>0471-259-9425 |
| Murty Srinivasula, Srinivasa<br>Associate Professor | Immunology<br>Cancer Biology | sms@<br>0471-2590-406 |
| Natesh, Ramanathan<br>Assistant Professor | Molecular Structural-<br>Biology | natesh@<br>0471-259-9403 |
| Nishant, K. T.<br>Assistant Professor | Meiotic recombination<br>Genome stability | nishantkt@<br>0471 259-0677 |
| Prasad, Kalika<br>Assistant Professor | Plant molecular<br>genetics & patterning | kalika@<br>0471-259-9404 |
| Radhakrishnan, Sunish<br>Assistant Professor | Cellular asymmetry<br>Cell division in bacteria | sunish@<br>0471-259-9401 |
| Somanathan, Hema<br>Assistant Professor | Insect navigation<br>Sensory ecology | hsomanathan@<br>0471-259-9424 |
| Kulkarni, M. B<br>Visiting Faculty, Pune Univ. | Bio statistics | madhavbk@gmail.c |
| Mathew, M. K<br>Visiting Faculty, NCBS | Neurobiology<br>Ion channels | mathew@ncbs.res.ir |

[1] Please suffix `iisertvm.ac.in` to the email address

## School of Chemistry

| Faculty members | Research interests | Contact details[1] |
|---|---|---|
| Datta, Ayan<br>Assistant Professor | Computational Chemistry<br>Theoretical Sciences | ayan@<br>0471-259-9417 |
| Gopinathan, M. S.<br>Professor | Quantum Chemistry<br>Non-linear dynamics | gopi@<br>0471-259-7428 |
| Hariharan, Mahesh<br>Assistant Professor | Physical organic chemistry<br>Biophysical chemistry | mahesh@<br>0471-259-9413 |
| Jemmis, E. D.<br>Professor and Director | Theoretical Chemistry<br>Computational Chemistry | jemmis@<br>0471-259-7421 |
| Sureshan, K M.<br>Assistant Professor | Medicinal chemistry<br>Chemical Biology | kms@<br>0471-259-9412 |
| Swathi, R S.<br>Assistant Professor | Theoretical chemistry | swathi@<br>0471-259-9404 |
| Thomas, George K.<br>Professor and Dean | Photochemistry<br>Hybrid nanomaterials | kgt@<br>0471-259-7425 |
| Varghese, Reji<br>Assistant Professor | Supramolecular chemistry<br>Functional DNA | reji@<br>0471-259-9427 |
| Venugopal, Ajay<br>Assistant Professor | Inorganic Chemistry<br>Organometallic | ajay@<br>0471 259-0677 |
| Vijayan, Vinesh<br>Assistant Professor | NMR Spectroscopy | vinesh@ |
| Padmanabhan, M<br>Visiting Faculty | | padmanabhan@<br>0471-259-7437 |

[1] Please suffix `iisertvm.ac.in` to the email address



## School of Mathematics

| Faculty members | Research interests | Contact details[1] |
|---|---|---|
| Dharmatti, Sheetal<br>Assistant Professor | Partial differential equations<br>Control theory | sheetal@<br>0471-259-9401 |
| Jayaraman, Sachindranath<br>Assistant Professor | Linear Algebra | sachindranathj@<br>0471-259-0487 |
| Manna, Utpal<br>Assistant Professor | Stochastic Processes<br>Partial differential equations | manna.utpal@<br>0471-259-9414 |
| Rajan, M. P<br>Associate Professor | Functional Analysis<br>Mathematical Finance | rajanmp@<br>0471-259-9411 |
| Vijay, Sujith<br>Assistant Professor | Combinotorial number theory<br>Ramsey theory on integers | sujith@ |
| Jyothilingam, P<br>Visiting Faculty | Commutative Algebra<br>Algebraic geometry | |
| Nanda, Tara R.<br>Visiting Faculty | Functional Analysis<br>Probability Theory | |
| Unnithan, S<br>Visiting Faculty | Statistics | |

[1] Please suffix `iisertvm.ac.in` to the email address

## School of Physics

| Faculty members | Research interests | Contact details[1] |
|---|---|---|
| Dutta, Sreedhar B<br>Assistant Professor | Nonequillibrium physics<br>Quantum statistical field theories | sbdutta@<br>0471-259-9421 |
| Jaiswal-Nagar, Deepshikha<br>Assistant Professor | Strongly correlated electron systems and Superconductivity | deepshikha@ |
| Kini, Rajeev N C<br>Assistant Professor | Teraherz spectroscopy & imaging | rajeevkini@<br>0471-259-9402 |
| Namboothiry, Manoj<br>Assistant Professor | Organic optoelectronics<br>Spintronics | manoj@<br>0471-259-9426 |
| Nath, Ramesh Chandra<br>Assistant Professor | Magnetism<br>Superconductivity | rnath@<br>0471-259-9427 |
| Mitra, Joy<br>Assistant Professor | Scanning probe microscopy<br>tunnelling induced luminiscence | j.mitra@<br>0471-259-9403 |
| Pai, Archana<br>Assistant Professor | Gravitational wave physics<br>Signal processing | archana@<br>0471-259-9423 |
| Shaijumon, M M<br>Assistant Professor | Nanomaterials<br>Energy Storage | shaiju@<br>0471-259-9402 |
| Shaji, Anil<br>Assistant Professor | Quantum information theory<br>Open quantum systems | shaji@<br>0471-259-9422 |
| Shankaranarayanan, S<br>Assistant Professor | Cosmology<br>Classical and quantum gravity | shanki@<br>0471-259-9415 |
| Thalakulam, Madhu<br>Assistant Professor | Electron transport in<br>Mesoscopic systems | madhu@ |

[1] Please suffix `iisertvm.ac.in` to the email address



| Faculty members | Research interests | Contact details[1] |
|---|---|---|
| Nayar, Unnikrishnan V<br>Visiting Faculty | Laser Spectroscopy | nayarvu@<br>0471-2599-416 |
| Shenoy, Subodh<br>Visiting Faculty | Condensed matter physics | subodhshenoy@ |

## Laboratory Coordinators

| | | |
|---|---|---|
| 1. Ganga Devi, T | School of Biology | gangadevi@<br>0471-2597-437 |
| 2. Thomas, O | School of Chemistry | othomas@ |

[1] Please suffix `iisertvm.ac.in` to the email address

# Administration

1. Prof. E. D. Jemmis
   Director
   jemmis@iisertvm.ac.in
   Tel: 0471-2597421

2. Prof. K. George Thomas
   Dean (Academics & Administration)
   kgt@iisertvm.ac.in
   Tel: 0471-2597425

3. Mr. Bharat Jyoti
   Registrar
   registrar@iisertvm.ac.in
   Tel: 0471-2597459

4. Mr. Hariharakrishnan
   Asst. Registrar (Administration, Academic)
   hariharan@iisertvm.ac.in
   0471-2597422

5. Mr. B. V. Ramesh
   Asst. Registrar (Finance)
   ramesh@iisertvm.ac.in
   0471-2597422

6. Mr. Sainul Abideen P
   Assistant Librarian
   sainul@iisertvm.ac.in
   0471-2599400

7. Mr. Sreekumar P. Y.
   Technical Officer
   sreekumarpy@iisertvm.ac.in