INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH THIRUVANANTHAPURAM

An autonomous institution under the

Ministry of Human Resource Development, Government of India

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

2014-15

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.
- To register for a course ALL prerequisites must be successfully completed. [1]
- Registration involves payment of the prescribed fees for the semester.
- Fine 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 CGPA (cumulative grade point average) of 6.5 out of 10 at the end of each academic year.

[1] refer page 7, clause 2 of Essentials for Completing Courses

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.

Leave

Application for leave of absence should be submitted in the format available from the Academic Office alongwith necessary supporting documents e.g. medical certificate, if applicable. Leave should not usually be availed without prior permission of the Dean/PhD Coordinator.

Semester Leave
A student can avail semester leave up to a maximum of two semesters during the entire duration of the programme, on bona fide grounds. The period of semester leave will not be counted in the prescribed time limit for completion of the Programme. Students will loose financial assistantship during the period of such extended leave. The leave request is to be forwarded by the research guide and Chairperson of the school (or DC) to the Dean and is to be approved by the Director. Applications must be submitted well in advance of the date of commencement of the leave requested.

Coursework

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 :

80% weightage will be given through a continuous evaluation (based on experiments performed and viva) conducted during the practical hours. All experiments will be given equal weightage and marks will be given on completion of each experiment and be recorded in the students laboratory note books. 20% weightage will be given for written/viva examinations conducted at the end of the semester.

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

In addition, there shall be two other grading symbols which can be used to indicate special status of a student in a course:

I - for "Incomplete"
W - for "Withdrawn"

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

$$\mathrm{SGPA} = \sum_i \mathrm{A}_i \mathrm{G}_i / \sum_i \mathrm{A}_i$$

Where, A_i = Credit for i^{th} course; G_i = Grade point secured by the student in the i^{th} course. Summation is over all the courses credited by the student in the particular *semester*.

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

$$\mathrm{AGPA} = \sum_j \mathrm{A}_j \mathrm{G}_j / \sum_i \mathrm{A}_j$$

Where, A_j = Credit for j^{th} course; G_j = Grade point secured by the student in the j^{th} course. Summation is over all the courses credited by the student in the particular *academic year*.

(d) Cumulative Grade Point Average is calculated as

$$\mathrm{CGPA} = \sum_k \mathrm{C}_k \mathrm{G}_k / \sum_k \mathrm{C}_k$$

Where, C_k = credit for k^{th} course; G_k = Grade point secured by the student in the k^{th} course. Summation is over all the courses *credited* by the student in *all the completed semesters, no course counting twice*. CGPA in the final transcript is to be calculated based on all course credits completed with a Pass Grade only.

Essentials for Completing Courses

1. Students are expected to attend all the classes. Students with overall 80% attendance or above will only be permitted to write the end semester examination. Attendance will be recorded in the prescribed book in every class and attendance percentage will appear in the grade transcript.

2. To register for any course a student must have completed ALL prerequisite courses (if any) with a D grade or better.

3. 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.

4. Repeat of a course is not permitted if a student has obtained a grade D or above.

5. The incomplete grade I is a *transitional* grade which will be given to the students who miss the end semester examinations under exceptional circumstances (e.g. serious medical reasons) as determined by the course instructor and the relevant School Coordinator and approved by the Dean (Academics).

   Make-up examination will be given to these students provided they meet 80% attendance and other academic requirements as per the rules and regulations of the institute.

   The actual grade obtained after the make-up examination will be taken and will reflect in the transcript replacing the I grade. In case a student obtains an F grade in the make-up examination, he/she will be eligible to write the repeat examination.

   Absence in the make-up examination will automatically lead to zero marks in that examination and the final grade in that course will be de-

termined based on the examinations taken in that course.

If the absence of a student in an examination is not approved by the Dean (Academics) (e.g. a deliberate attempt to skip the examination), he/she will be awarded zero marks in that particular course examination. The final grade in that course will be determined based on the other examinations of that course taken by the student.

6. Withdrawal of a registered course in a semester is usually permitted/enforced in very special cases, e.g. due to prolonged illness. W grade is given in these circumstances and the student is asked to repeat the concerned course with same course number taking all examinations when offered next. The new grade obtained by the student will be taken into consideration and appear in the transcript. However, the previous W grade will also appear in the transcript.

7. W grade will not have any effect in the calculation of SGPA, AGPA and CGPA. If a student has W grade in a registered course in a particular semester, SGPA will be calculated based on the grades obtained in other registered courses of that semester. Same rule applies to the calculation of AGPA and CGPA.

8. If a student does not clear a CORE course, 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 passed by the student, it is treated as a *backlog* in the student's records. Both the grades, the new grade and the previous F grade, will appear in the grade transcripts.

9. An F grade obtained in a course will contribute to the CGPA until;
(i) a course with the same course number is completed with a D grade or better (applicable for foundation and core courses), or
(ii) substituted with an alternative/same course and completed with a D grade or better (applicable *only* for minor/elective courses) or
(iii) The necessary credit requirements for continuing in the Integrated PhD programme are satisfied.

Course Feedback

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

Re-evaluation of End Semester Examination Answer Sheets

Request for re-evaluation of answer sheets should be given by the student within 7 days of the announcement of end semester results as a written request to the Academic Office and by paying a prescribed re-evaluation fee.

Requirements for continuing in the Integrated Ph.D. Programme

1. The minimum number of successfully completed credits is 60 in four semesters. Research work (if any) will constitute 6 credits.
2. CGPA must be 6.5 or above.
3. Pass the comprehensive examination (as specified by the individual Schools).

ALL the above requirements must be satisfied to continue in the doctoral programme. Individual Schools are free to place additional requirements; pertaining to minimum credit requirements, the nature of comprehensive examination and how the credits are split between theory and laboratory courses.

Comprehensive examination

1. After completing 60 credits, students with a CGPA of 6.5 or above are required to pass a comprehensive examination, in order to continue in the doctoral programme.
2. The comprehensive examination must be passed in a maximum of two attempts.

Removal from the rolls

A student will be removed from the rolls under any of the following circumstances.

1. Failure to maintain a minimum CGPA of 6.5 at the end of each academic year, will lead to removal of the student from the rolls.
2. A second failure in the comprehensive examination will lead to removal of the student from the rolls.
3. Failure to clear any course even after repeating the same course will lead to the removal of the student from the rolls.
4. ALL courses and project work must be successfully completed in four semesters and a relaxation to a maximum of six semesters may be allowed under exceptional circumstances, on approval of the Chairman, Senate. Failure to do so will lead to the removal of the student from the rolls.
5. A student may also be removed from the rolls as a result of disciplinary action for serious misconduct and/or violation(s) of the Code of Conduct of the Institute.

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

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

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* *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, W=Withdrawn

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

Research work

Starting of the research work and Supervisor

After the successful completion of the course work and comprehensive examination, 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. The major role of the DC 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 DC 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 report.
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

Conduct and Discipline

Code of Conduct

Disciplinary policies of Indian Institute of Science Education and Research Thiruvananthapuram (IISER-TVM) are put in place to ensure a secure academically enriching environment for all members of the community and to promote civility on campus. Students of IISER-TVM are expected to show personal integrity, respect for Institute resources, and respect for others rights, for the values of scholarship and teaching. Students are expected to adhere to the institute rules and regulations. Any violation will be handled according to the rules set forth by the Senate and Board of Governors of IISER-TVM. The administrators of the institute may notify parents/guardians if a student behaves recklessly or his/her academic career is in serious jeopardy.

Any of the following shall constitute violation of the Code of Conduct for students and makes the student liable to disciplinary action by the Institute.

- Lack of courtesy and disorderly conduct or disruptive acts (within or outside Institute premises).
- Any act that compromises the safety/security of individuals or Institutional facilities.
- Wilful damage or unauthorized removal of Institute property.
- Unauthorized access to institutional facilities/records.
- Tampering of data/records (reading, copying or destroying).
- Any act of fraud/misrepresentation/dishonesty.
- Misappropriation of any belongings of fellow students/staff/faculty.
- Adoption of unfair means during examinations or misconduct in research.
- Infringement of personal privacy.
- Ragging in any form.
- Caste/religion/ethnicity/gender/physical disability based discriminatory behaviour/remarks.

- Sexual harassment/assault.
- Possession of banned substances or dangerous items (illegal drugs, weapons, firearms etc.) that endangers safety of student himself/herself or others.
- Any act that affects the reputation/orderly conduct of the institute.

THE DISCIPLINARY PROCEDURE

1. The Students Disciplinary Committee (SDC) of the Institute is constituted under the chairmanship of a faculty member by the Director. Depending on the issues of allegations involved, the Chairman of the SDC may invite additional members, for example the Coordinator of BS-MS/PhD Programme, students faculty advisor/research supervisor, Deputy Registrar (Academics & Administration) in case of academic related issues, to facilitate with the investigation.
2. SDC will investigate the allegations of misdemeanours or violation of the Code of Conduct, without bias. The SDC will subsequently submit a fact-finding report and recommend disciplinary action(s), if any, to the Dean, Student Affairs.
   Complaints related to caste/religion/ethnicity/gender-specific discrimination and sexual harassment will be investigated by an appropriate committee of the Institute and will report directly to the Director.
3. While hearing the disposition of the accused student(s) and witnesses, the Chairman, SDC may invite two senior student observers, from the BS-MS (5th Yr) and PhD/IPhD programmes respectively, to be present with the SDC.
4. The student observers are to be invited by the Chairman, SDC in consultation with the Dean, Student Affairs, from a list of nominees forwarded by the Schools. The list of nominees is valid for a year.
5. The student observers shall withdraw at the conclusion of the above and may submit their remarks (if any) in writing to the Chairman, SDC for consideration.
6. The Chairman, SDC, shall keep records of the entire proceedings of the meetings.
7. All disciplinary actions shall be notified in writing to the concerned students and their parents/guardians by the Office of the Registrar.

8. A student who feels aggrieved with the disciplinary action may appeal to the Director. The appeal has to be filed within a period of one month from the date of intimation of disciplinary action stating clearly the case and explaining his/her position and reason(s) for reconsideration of the decision.

DISCIPLINARY ACTIONS

Violation of the Code of Conduct shall invite disciplinary action, which may include penalties such as, reprimand, fine, suspension/expulsion from the hostel, debarring from examinations, withdrawing/withholding of scholarship/fellowship/benefits or access to institute facilities, withholding of grades and/or degrees and suspension for a certain period or even permanent expulsion from the Institute.

The Senate may withhold recommendation of a student, who is found guilty of a major offence, to the Board of Governors for the award of a degree, even if the student has satisfactorily completed all the academic requirements.

Lack of knowledge of the rules and regulations is not an admissible excuse or defence for misconduct/dishonesty, and shall not be a basis for leniency.

DISCIPLINARY ACTION FOR MALPRACTICES IN RESEARCH:

Students involved in conducting research at IISER-TVM are expected to maintain highest standards of integrity. Any form of unscrupulous conduct will be investigated by competent authorities and could warrant a variety of disciplinary actions, in severe cases cancellation of Ph.D. registration or even cancellation of an awarded Degree at any time.

Research misconduct can take place in many forms, including deliberate interference with the integrity of the work of others, plagiarism, falsification of data, and fabrication of data. In particular, students are expected to observe the practice of acknowledging source(s) of information reproduced in his/her thesis, reports, publications, or seminars.

Plagiarism includes, without citation, the appropriation of other's text, results, or ideas.

Falsification includes actions such as not accurately representing research records or results, manipulating reagents or equipment settings, to produce a preconceived outcome.

Fabrication includes making up data and recording them.

Honour Pledge

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 practices.
   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/- Sd/-
   Student Parent/Guardian

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

Library Regulations

1. Library Hours:
   a. Monday to Friday: 9 AM to 7.30 PM
      Saturday: 9 AM to 5 PM
      Sunday: Closed
   b. During Exam Week: 9 AM to 10 PM.
   c. Circulation Timings: 9.15 AM to 5.15 PM (Monday - Friday); 9:00 AM - 12:00 Noon (Saturday)
2. All registered IntPhD students are eligible for membership in the institute library.
3. IntPhD students can borrow maximum 4 books at a time for 2 weeks, provided they do not have any overdue book. IntPhD students, who have successfully completed their MS course work can borrow 10 books for 60 days. (Note: Some books may have a shorter loan period depending on the demand).
4. Users must leave their bags and other belongings outside the Library. Only notebooks and papers are allowed inside the library. Borrowed books are allowed to be taken to the library for return/renewal only. All items taken out of the library (including personal items, if any) 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. Identity card is mandatory for borrowing books from the Library.
6. Strict silence has to be maintained by all users inside the Library.
7. Use of Mobile Phones, Laptops, consumption of food and drinks are strictly prohibited inside the Library.
8. Use of the user PC kept inside the library is allowed for accessing, library catalogue, e-journals, e-books and academic databases only.
9. Return of book is mandatory before the due date. A fine of Rs 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 any time 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.

10. Any book, including reference books can be borrowed for overnight reference, at the closing time of the library and to be returned at 9 AM on the next working day. Only one book can be borrowed for overnight reference. A late fee of Rs 50/- per day per book for the delayed return of such book will be charged.
11. 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 ensure the condition of the book and bring to the notice of the library staff, if any mutilation is found.
12. Members who lose/mutilate library books are liable to replace it with its latest edition along with a penalty of 20% of the total cost of the book. All such replaced books 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.
13. IntPhD students should return all the books they borrowed before they go for vacation.
14. Users should obey the library rules and regulations. Violation of rules and any act of misbehaviour will be brought to the notice of the Library Committee Chair, and will lead to strong disciplinary action.

Hostel Regulations

1. Any kind of loud noise in the rooms, corridors and premises of the hostel, especially during night, is prohibited.
2. Students are required to take care of their personal belongings, keep the respective rooms clean and the hostel premises tidy.
3. Students are required to take utmost care for the hostel furniture, TV, washing machines, building structure, electrical fittings etc.
4. Students should strictly avoid getting into arguments with fellow hostellites, localites and security officers/matrons of the hostel.
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. 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.
9. Please take care of your personal belongings.
10. Anti-ragging regulations of the institute have to be strictly followed in the hostels too.
11. Use of drugs/alcoholic beverages/tobacco products in the hostels is strictly prohibited. Smoking in public is a punishable offence.
12. Students should be either in the hostel or in the Institute. Prior permission from the concerned warden and matron have to be obtained in case the student plans to go anywhere else for a few hours. This has also to be recorded in the register kept with the matron/security in the Hostel.
13. All students must return to their respective hostels by 10.00 pm.
14. Leaving the hostel for a day or longer need prior permission from the faculty advisor of the student and the PhD coordinator with mandatory intimation to concerned matron and warden. Students are required to fill up the leave application form available from the Academic Office and get it signed by the appropriate authority. The form should be submitted to the Academic Office with a copy to the concerned matron/warden/security of the hostel.
15. Permanent address including the phone numbers of the parent(s)/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 parents 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 LSC (LTPC) XYZ LSCD (LTPC)

respectively. The numbering may be understood as

XYZ	:	Subject Code
L	:	Level of the course (3, 4 or 5)
S	:	Semester (1 = Varsha, 2 = Vasant)
C (CD)	:	Course number (in a particular subject)
L	:	Lecture hours
T	:	Tutorial hours
P	:	Practical hours
C	:	Credits

Subject Codes (XYZ)

BIO : Biological Sciences
CHY : Chemical Sciences
MAT : Mathematical Sciences
PHY : Physical Sciences

Minimum Credit Requirement

The minimum number of credits required to sucessfully complete the Integrated PhD programme 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 6.5. 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 42XX	Elective – I	3	0	0	3
BIO 412	Biostatistics	3	0	0	3		BIO 42XX	Elective – II	3	0	0	3
BIO 413	Plant Molecular Genetics	3	0	0	3		BIO 42XX	Elective – III	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 (35).

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 42XX	Elective – I	3	0	0	3
CHY 412	Advanced Chemical Kinetics	3	0	0	3		CHY 42XX	Elective – II	3	0	0	3
CHY 413	Advanced Organic Chemistry-II	3	0	0	3		CHY 42XX	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 (47).

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	Abstract Algebra	3	0	0	3	MAT 322	Measure Theory and Integration	3	0	0	3
MAT 313	Advanced Linear Algebra	3	0	0	3	MAT 323	Galois Theory & Commutative Algebra	3	0	0	3
MAT 314	Numerical Analysis	3	0	0	3	MAT 324	Multivariate Analysis	3	0	0	3
MAT 3101*	Elective I- Operation Research	3	0	0	3	MAT 325	General Topology	3	0	0	3
Total		**15**	**0**	**0**	**15**	**Total**		**15**	**0**	**0**	**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**
MAT 411	Functional Analysis	3	0	0	3	MAT 42XX	Elective-III	3	0	0	3
MAT 412	Probability Theory & Random Processes	3	0	0	3	MAT 42XX	Elective-IV	3	0	0	3
MAT 413	Number Theory and Cryptography	3	0	0	3	MAT 42XX	Elective-V	3	0	0	3
MAT 414	Theory of Ordinary Differential Equations	3	0	0	3	MAT 42XX	Elective-VI	3	0	0	3
MAT 415	Reading Seminar	0	0	3	1	MAT 42XX	Elective-VII	3	0	0	3
MAT 4101*	Elective II- Programming & Data Structures	2	0	2	3						
Total		**14**	**0**	**5**	**16**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fourth Year: 61											

Remark 1: *The electives MAT 3101/ MAT 4101are compulsory and will be offered in every alternate year.*

Remark 2:- *The school is not obliged to offer an elective in a particular semester if situation warrants.*

For details of the course offered by the School of Mathematics, please turn to Page(67)

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 42XX	Elective-III	3	0	0	3
PHY 412	Condensed Matter-II	3	0	0	3		PHY 42XX	Elective-IV	3	0	0	3
PHY 413	Quantum Mechanics-II	3	0	0	3		PHY 42XX	Elective-V	3	0	0	3
PHY 41XX	Elective-I	3	0	0	3		PHY 42XX	Elective-VI	3	0	0	3
PHY 41XX	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 (81).

Biology Syllabus

Theory Courses

BIO 311 Microbiology [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 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 protein production.

BIO 312 Immunology [3003]

Introduction, Organization of the immune system (lymphoid tissues and organs).

Immune cell development (hematopoiesis, T and B cell development).

Innate and adaptive immunity (including cellular and humoral responses).

Antigens and Antibodies (antibody classes, Ag/Ab structure and function).

Immune signaling (T cell receptor, TLRs, inflammatory and cytokine responses).

The MHC and Ag presentation.

Immunity mechanisms in disease (allergies, autoimmunity, immunodeficiency).

Immunotherapy (clinical use of monoclonal antibodies).

Tumour Immunology.

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 tools to study cellular functions.

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

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

Components of the cytoskeleton and their regulations: organization and function of actin, intermediary filaments, microtubules and motor proteins, integrins, cadherins.

Cell-cell signaling: overview of extracellular signaling, cell surface receptors, regulation of signaling pathways: receptor RTK kinase, and integrin signaling Biochemical pathways in signal transduction: GPCR, insulin and EGF signaling.

Cell cycle and its control: mechanisms of growth and division of eukaryotic cells, cell cycle checkpoints.

Cell death: Apoptosis pathways.

BIO 314 Evolutionary Ecology [3003]

Recapitulation of fundamental concepts of evolution.

Evolution of antipredatory strategies: Mimicry, aposematism, crypsis, camouflage, etc; Anti-herbivory strategies in plants.

Phylogenetics and Biogeography: Basic phylogenetic methods, Historical biogeography and phylogeography, Comparative methods in evolutionary biology, Latitudinal diversity gradient.

Coevolution: Evolutionary arms race, Mutualism (including pollination and other insect-plant interactions), Community patterns, Plant-animal interactions, Multispecies interactions.

Phenotypic plasticity.

Sensory ecology: Signalling, communication, sensory systems, plant signalling and communication.

Evolution of sex and sexual selection: Sexual and asexual reproduction, sexual dimorphism, Sexual selection.

Life history: Life history strategies, ageing.

Chronobiology.

Human evolution.

BIO 321 Bacterial Genetics [3003]

PREREQUISITE

1. BIO 311 - Microbiology

Bacterial chromosome structure and replication, 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, conjugation, transformation, transduction as a tool in bacterial genetics, recombination, gene expression and transcriptional regulation in bacteria, post-transcriptional regulation in bacteria, Function and use of Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR).

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, Anfinsen and the protein folding problem; Action of other biologically important molecules and molecular assemblies like ribosomes, chaperones etc. in protein folding.

Conformational analysis: Covalent interactions, non-Covalent interac-

tions and their roles in protein structure; Van der Waals radii of atoms (equilibrium separation between non covalently bonded atoms) contact distance criteria; Non-covalent forces determining biopolymer structure; dispersion forces.

Introduction to bioinformatics: Biological databases, data mining -homology v/s similarity - dot matrices - sequence comparison using Needleman and Wunsch method - BLAST and FASTA - Structure analysis distance matrices -examples.

Physical instruments and methods: Purification and characterization of Proteins; Methods of protein purification, Principles of Chromatography; Proteomic tools: peptide mapping; characterization by coordinates in 2D gels, RPHPLC, Mass spectroscopy, Circular Dichroism.

Structural Biology methods for determination of macromolecular structures:

Biological NMR in Structural Biology: Basics of NMR, Nuclear spins, chemical shifts and J couplings; Strategies for structure determination - isotope labeling, High resolution multidimensional NMR, 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: External features and symmetry, 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, computer simulation, graphics and structural validation.

BIO 323 Advanced Biochemistry [3003]

Introduction.

Omics: metabolomics and proteomics.

Separation techniques: gas chromatography (GC), capillary electrophore-

sis (CE), high performance liquid chromatography (HPLC), ultra performance liquid chromatography (UPLC).

Combination of Techniques: GC-MS, HPLC-MS.

Detection techniques: nuclear magnetic resonance spectroscopy (NMR), mass spectrometry (MS), 2-D electrophoresis.

Proteins classes for analyses: membrane, soluble, nuclear, chromosome-associated complexes.

Carbohydrate metabolism: Glycolysis, gluconeogenesis, glycogen synthesis and breakdown, enzymatic mechanisms, reciprocal regulations and hormonal regulations pentose phosphate pathway, Krebs or TCA cycle (PDH complex, cofactors, TPP), amphibolic nature of citric acid cycle, regulation of CAC, oxidative phosphate pathways, respiration, proton transport, electron carriers glutathione and NADPH.

Fatty acid metabolism: fatty acid oxidation, beta-oxidation pathway, fatty acid synthesis, cholesterol synthesis.

Amino acid metabolism: Nitrate and ammonium assimilation; amino acid biosynthesis, degradation, urea cycle, heme synthesis.

Nucleic acid metabolism: purine and pyrimidine biosynthesis.

Bioenergetics: Oxidation reduction reactions.

Molecular chaperones in protein folding, experimental strategies to study protein mis-folding and disease.

BIO 324 Neurobiology [3003]

Historical overview from Empedocles to Bernstein; The Nernst Potential and Cable Equations; Resting and Action Potentials; Hodgkin & Huxley; Electrophysiological recording techniques; Voltage Gated Ion Channels; Ligand gated Ion Channels; Electrical & Chemical Synapses; Synaptic Plasticity; Sensory Physiology: Vision, Hearing, Somatosensory; Motor systems and Central Pattern Generators; Optical methods of detection and stimulation; Energetics of the Nervous System.

BIO 411 Developmental Biology [3003]

Basic Concepts and history of developmental biology; Model systems: lower eukaryotes, plants and animal model organisms; Morphogenesis and development of body plan; Cellular differentiation and Organogenesis; Growth and post-embryonic development; Germ cells and sex determination; Regeneration and tissue repair; Plant development: regulation of flowering time; Floral organ patterning; Evolution and development; Defects in development and diseases.

BIO 412 Biostatistics [3003]

Discrete and continuous 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.

BIO 413 Plant Molecular Genetics [3003]

A general introduction to embryonic and postembryonic plant development, regulatory action of plant hormones in controlling the continuous patterning, Enhancer and suppressor screens to design regulatory network, 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 of shoot and root meristem function.

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, pluripotency, multipotency and totipotency in plants.

Polarity: Plant cell polarity, mechanisms of onset of polarity in plant cell, hormonal flux controlling the polarity, link between cell fate and cell po-

larity.

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 hormone regulating architecture.

Evolutionary developmental biology: morphological diversity in different plant species utilizing conserved regulatory module.

BIO 414 Genomics [3003]

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: genome sequencing, personalized medicine.

Genome evolution: stability of haploid versus diploid genomes, plasticity of genomes, inter-species variation, genetic incompatibilities, gene duplication.

Electives Courses

BIO 4201 Mathematical and Systems Biology [3003]

Growth (Models, ideas); Mathematical modeling; Snowcaps; Steady states, stability analysis; Vectors; Epidemiology (SIFS); Chemical kinetics; Systems biology (Multi-stability); Periodic behavior; Periodic orbits, limit cycles; Hopf bifurcation; Neural systems; Logistic equations; Travelling waves; Reaction diffusion.

BIO 4202 Advanced Physiology [3003]

Animal physiology: Mechanisms and origin of animal physiology.

Nervous system and Sensory processing: central and peripheral nervous system; sensory systems-vision, hearing, taste, smell and touch.

Endocrine system and Reproduction: endocrine glands and functions; neuroendocrine systems; reproductive physiology.

Biological Clocks: internal biological clocks; circadian rhythms.

Feeding and Digestive system: nutrition, feeding and digestion; energy metabolism.

Thermoregulation: temperature regulation in warm and cold-blooded animals.

Muscular system and movement: control of movement; muscle types and functions.

Respiratory system: physiology of breathing; transport of oxygen and carbon dioxide, oxygen and evolution of animals.

Circulatory system: circulatory systems in invertebrates and vertebrates.

Excretory system: managing water, salt and body fluids in animals.

Environment and physiology: influence of environment on animals, adaptations to extreme environments.

Animal navigation and migration: why and how do animals migrate? Physiological changes during migration, Physiological diseases.

Plant physiology: Photosynthesis and photorespiration Light harvesting complexes, photosynthetic pigments and its biosynthesis, mechanisms of Co2 fixation, photorespiratory pathway and way to avoid photorespiration - recent advances in C3-C4 pathway engineering.

Sensory photobiology: Structure, function and mechanisms of action of phytochromes, cryptochromes and phototropins, photoperiodism and circardian rhytmns in plants.

Phytohormones: Auxin, cytokinin, giberellic acid, ethylene, salicylic acid, jasmonates, brassinosteroids,strigolactones - biosynthesis, transport, mode of action and its physiological role in plant development.

Secondary metabolites: Mevalonate and MEP/DOXP pathway, shikimate pathway, malonate pathway for biosynthesis of terpenoids, phenolics al-

kaloids their derivatives, recent advances in metabolic engineering.

Stress physiology: Responses of plants to biotic (pathogen and insects) and abiotic (water, temperature and salt) stresses; mechanisms of resistance to biotic stress and tolerance to abiotic stress.

BIO 4203 Advances in Molecular Biology [3003]

Chromatin: Nucleosomes, higher order chromatin organization, chromatin modifications and chromosome function.

Molecular aspects of replication, RNA processing, transcription and translation.

Epigenetics: DNA methylation in prokaryotes and eukaryotes, epigenetic gene regulation by DNA methylation in plants and mammals.

Protein-nucleic acid interactions - nucleic acid recognition by proteins - binding motifs - techniques to study protein-nucleic acid interactions.

Non-coding RNA: Biogenesis and its function.

Genome instability: Aneuploidy, haploidy and polyploidy.

Recombinant DNA technology and molecular cloning.

List of Further Electives in Biology

1. Advanced topics in ecology, evolution and behaviour (primary literature and book chapter discussion)
2. Biodiversity and field biology
3. Advanced immunology
4. Prokaryotic development
5. Cancer biology
6. Special topics in genetics and chromosome biology
7. Treatise on molecular structural biology
8. Techniques in 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.

Chemistry Syllabus

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 σ - and π-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*, 2^{nd} Ed., Academic Press (2008).
3. D. Banerjea, *Coordination Chemistry*, Asian Books Pvt Ltd. (2007).
4. N. N. Greenwood and A. Earnshaw, *Chemistry of Elements*, 2^{nd} 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*, 4^{th} 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*, 4^{th} Ed., Oxford University Press (2008).
9. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models in Inorganic Chemistry*, 3^{rd} 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*, 3^{rd} Ed., Elsevier.
2. I. N. Levine and K. A. Peterson, *Quantum Chemistry*, 5^{th} 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, chi-

rality 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*, 5^{th} Ed., John Wiley and Sons, 1992.
2. E. L. Eliel, *Stereochemistry of Carbon Compounds*, Tata McGraw-Hill Edition 1975, 38^{th} reprint 2008.
3. D. Nasipuri, *Stereochemistry of Organic Compounds-Principle and Applications*, 2^{nd} Ed., New Age International Publishers, 2007.
4. P. S. Kalsi, *Stereochemistry-Conformation and Mechanism*, 7^{th} 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*, 5^{th} Ed., Brooks Cole.
2. H. Willard, L. Merritt and J. Dean, *Instrumental Methods of Analysis*, 7^{th} 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 σ-donor and π-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 β-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*, 4^{th} 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*, 4^{th} Ed., Oxford University Press (2008).
4. J. P. Collman, Hegedus, Nortaon and Finke, *Principles and Application of Organo-transition Metal Chemistry*, 2^{nd} Ed., (1987).
5. J. D. Atwood, *Inorganic and Organometallic Reaction Mechanism*, 2^{nd} 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* 2^{nd} Ed., New Age International Publication (2000).
9. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models if Inorganic Chemistry*, 3^{rd} 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, sterosselective 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*, 2^{nd} 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*, 2^{nd} 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, β-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, α-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*, 2^{nd} Ed., Cambridge University Press (1987).
3. L. E. Smart and E. A. Moore, *Solid State Chemistry: An introduction*, 3^{rd} 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*, 2^{nd} 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*, 3^{rd} 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*, 8^{th} 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*, 3^{rd} 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*, 4^{th} Ed., Pearson Education, (2008).
2. F. A. Cotton, G. Wilkinson, C. A. Marillo and M. Bochmann, *Advanced Inorganic Chemistry*, John Wiley, (2003).
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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

Theory Courses

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: 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 313: 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 314: 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: σ-algebras of sets, Borel sets, outer measure and its properties, σ-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 312-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: Multivariable Analysis [3003]

PREREQUISITES

1. MAT 311-Real Analysis
2. MAT 313-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 π, 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.

List of Electives

1. Functional Analysis
2. Partial Differential Equations
3. Discrete Mathematics
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

Physics Syllabus

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]

Introduction to conductors, semiconductors and insulators. Band structure, mechanism of conduction, doping and PN junction formation. Basic semiconductor devices: PN junctions, bipolar transistors and operation.

Norton and Thevnin's Theorem rectifiers and filters: L, C, RC, LC and LCR filters.

AC and DC analysis of transistor circuits amplifiers and differential amplifiers.

Operating principles of FET, MOSFET and Operational amplifiers.

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.

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* (2^{nd} Ed.), John Wiley & Sons, 1991.
3. H. B. Callen, *Thermodynamics and an Introduction To Thermostatistics*, Wiley, 2006.
4. R. K. Pathria, *Statistical Mechanics* (2^{nd} 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]

Heterojunction Properties, Special purpose diodes: Zener, Varactor diode, Tunnel diode, Diac, Triac, LED, PV cell, Photodetectors, SCR, UJT, IGBT. Oscillators design and applications. Power amplifiers.

Advanced Electronic Materials: Optoelectronic properties and applications.

Digital Electronics:
Boolean algebra, De Morgan's theorem, Karnaugh Map, Logic gates, adder circuits.

Digital analog and Analog Digital Converters.

Flip-flops, Counters and Shift registers.

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.

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 electromagnetic 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. Torsion Pendulum Rigidity Modulus
3. Young's Modulus: Cornu's Method (Elliptical & Hyperbolic Fringes)
4. Spectrometer: $i - i'$ curve
5. Spectrometer Hartmann's formula (finding unknown wavelength)
6. Young's Modulus Optic Lever Method
7. Surface Tension Capillary Rise (Water) Method, Capillary Dip (Mercury) Method and Quinke's Method (Mercury)
8. Beam Profile of Laser Divergence of Laser Beam
9. Diffraction by ultrasonic waves Velocity of Sound in Liquid
10. e/m - Thomson's Method
11. Fabrey-Perot Interferometer
12. Michelson's Interferometer
13. LCR circuit (Series and Parallel) Frequency Response and Value of Unknown L
14. AC Bridges Anderson, Maxwell, DeSauty, Owen (any two)
15. Photo-diode Characteristics (Intensity vs. Photo current, dark resistance of photo diode)
16. Transistor Characteristics (common emitter)
17. Transistor as a Switch and Amplifier
18. Voltage Controlled Oscillator (Transistor/555 timer): Variation in frequency with control voltage
19. Colpit, Hartley, Phase-shift & Wein-bridge Oscillators (Transistor) (any two)
20. Mono-stable Multivibrator and 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. Zeeman Effect
2. Nuclear Magnetic Resonance
3. Hall Effect

4. Electron Spin Resonance
5. Band gap of a semiconductor
6. Magnetic susceptibility - Quincke's Method
7. $B - H$ Curve (ferromagnet)
8. Optical Pumping
9. Two slit Interference - one photon at a time
10. Damped-Driven Pendulum
11. GM Counter
12. Fiber optics or Optical fiber characteristics
13. Thin film deposition and characterization

Deans and Coordinators

1. Prof. K. George Thomas
   `Dean (Academics and Faculty Affairs)`
   `Coordinator, School of Chemistry`
   e-mail: kgt@iisertvm.ac.in Tel: 0471-2597425

2. Prof. Srinivasula Srinivasa Murty
   `Dean (Students Affairs)`
   `Coordinator, School of Biology`
   e-mail: sms@iisertvm.ac.in Tel: 0471-2590406

3. Dr. M. P. Rajan
   `Associate Dean (R&D Consultancy)`
   `Coordinator, School of Mathematics`
   e-mail: rajanmp@iisertvm.ac.in Tel: 0471-2599411

4. Dr. S. Shankaranarayanan
   `Coordinator, School of Physics`
   e-mail: shanki@iisertvm.ac.in Tel: 0471-2599415

5. Dr. K. M. Sureshan
   `Coordinator, BS-MS Programme`
   e-mail: kms@iisertvm.ac.in Tel: 0471-2599412

6. Dr. Joy Mitra
   `Coordinator, PhD and IPhD Programmes`
   e-mail: j.mitra@iisertvm.ac.in Tel: 0471-2598408

7. Dr. Utpal Manna
   `Coordinator, Hostel Administration`
   e-mail: manna.utpal@iisertvm.ac.in Tel: 0471-2599414

8. Dr. Anil Shaji
   `Coordinator, Campus Development`
   e-mail: shaji@iisertvm.ac.in Tel: 0471-2599422

Faculty

SCHOOL OF BIOLOGY

1. Dr. Ullasa Kodandaramaiah
   e-mail: ullasa@iisertvm.ac.in Tel: 0471-2599424

2. Dr. Tapas Manna
   e-mail: tmanna@iisertvm.ac.in Tel: 0471-2599425

3. Dr. Ravi Maruthachalam
   e-mail: ravi@iisertvm.ac.in Tel: 0471-2599425

4. Prof. Srinivasula Srinivasa Murty
   e-mail: sms@iisertvm.ac.in Tel: 0471-2590406

5. Dr. Ramanathan Natesh
   e-mail: natesh@iisertvm.ac.in Tel: 0471-2599403

6. Dr. Kalika Prasad
   e-mail: kalika@iisertvm.ac.in Tel: 0471-2597438

7. Dr. Sunish Kumar Radhakrishnan
   e-mail: sunish@iisertvm.ac.in Tel: 0471-2599401

8. Dr. Hema Somanathan
   e-mail: hsomanathan@iisertvm.ac.in Tel: 0471-2599424

9. Dr. Nishant K.T.
   e-mail: nishantkt@iisertvm.ac.in Tel: 0471-2590677

10. Dr. Jishy Varghese
    e-mail: jishy@iisertvm.ac.in Tel: 0471-2590526

SCHOOL OF CHEMISTRY

1. Dr. Mahesh Hariharan
e-mail: mahesh@iisertvm.ac.in Tel: 0471-2599413

2. Dr. Adithya Lakshmanna
e-mail: adithya@iisertvm.ac.in

3. Dr. Sukhendu Mandal
e-mail: sukhendu@iisertvm.ac.in Tel: 0471-2590697

4. Dr. Kana M. Sureshan
e-mail: kms@iisertvm.ac.in Tel: 0471-2599412

5. Dr. R. S. Swathi
e-mail: swathi@iisertvm.ac.in Tel: 0471-2599404

6. Dr. A. Thirumurugan
e-mail: thiru@iisertvm.ac.in Tel: 0471-2590678

7. Prof. K. George Thomas, FASc
e-mail: kgt@iisertvm.ac.in Tel: 0471-2597425

8. Dr. Reji Varghese
e-mail: reji@iisertvm.ac.in Tel: 0471-2599427

9. Dr. Ajay Venugopal
e-mail: venugopal@iisertvm.ac.in Tel: 0471-2590677

10. Dr. Vinesh Vijayan
e-mail: vinesh@iisertvm.ac.in

11. Prof. M. S. Gopinathan, FASc, FNA
e-mail: gopi@iisertvm.ac.in Tel: 0471-2597428

12. Prof. M. Padmanabhan
    Guest Faculty
    e-mail: padmanabhan@iisertvm.ac.in

13. Prof. Sankaran Subramanian
    Guest Faculty

SCHOOL OF MATHEMATICS

1. Dr. K. R. Arun
   e-mail: arun@iisertvm.ac.in Tel: 0471-2590697

2. Dr. Sheetal Dharmatti
   e-mail: sheetal@iisertvm.ac.in Tel: 0471-2599401

3. Dr. Sachindranath Jayaraman
   e-mail: sachindranathj@iisertvm.ac.in Tel: 0471-2590487

4. Dr. Utpal Manna
   e-mail: manna.utpal@iisertvm.ac.in Tel: 0471-2599414

5. Dr. M. P. Rajan
   e-mail: rajanmp@iisertvm.ac.in Tel: 0471-2599411

6. Dr. Viji Z. Thomas
   e-mail: vthomas@iisertvm.ac.in

7. Dr. Guram Donadze
   Guest Faculty
   e-mail: gdonad@gmail.com

8. Prof. Tara Nanda
   Guest Faculty
   e-mail: tarananda@usa.net

SCHOOL OF PHYSICS

1. Dr. Sreedhar B. Dutta
e-mail: sbdutta@iisertvm.ac.in Tel: 0471-2599421

2. Dr. Rajeev Naveenchandra Kini
e-mail: rajeevkini@iisertvm.ac.in Tel: 0471-2599402

3. Dr. Amal Medhi
e-mail: amedhi@iisertvm.ac.in

4. Dr. Joy Mitra
e-mail: j.mitra@iisertvm.ac.in Tel: 0471-2598408

5. Dr. Deepshikha Jaiswal Nagar
e-mail: deepshikha@iisertvm.ac.in Tel: 0471-2590526

6. Dr. Manoj Namboothiry
e-mail: manoj@iisertvm.ac.in Tel: 0471-2599426

7. Dr. Ramesh Chandra Nath
e-mail: rnath@iisertvm.ac.in Tel: 0471-2599427

8. Dr. Archana Pai
e-mail: archana@iisertvm.ac.in Tel: 0471-2599423

9. Dr. Ravi Pant
e-mail: rpant@iisertvm.ac.in

10. Prof. V. Ramakrishnan, FTNASc
e-mail: ramakrishnanlaser@iisertvm.ac.in Tel: 0471-2597421

11. Dr. Bindusar Sahoo
e-mail: bsahoo@iisertvm.ac.in

12. Dr. M. M. Shaijumon
e-mail: shaiju@iisertvm.ac.in Tel: 0471-2599402

13. Dr. Anil Shaji
    e-mail: shaji@iisertvm.ac.in Tel: 0471-2599422

14. Dr. S. Shankaranarayanan
    e-mail: shanki@iisertvm.ac.in Tel: 0471-2599415

15. Dr. Madhu Thalakulam
    madhu@iisertvm.ac.in Tel: 0471-2590307

16. Prof. Unnikrishnan Nayar
    Guest Faculty
    e-mail: nayarvu@iisertvm.ac.in Tel: 0471-2599416

HONORARY PROFESSOR

1. Prof. R. Balasubramanian, FASc, FNA, FNASc
   Director, Institute of Mathematical Sciences, Chennai
   e-mail: director@imsc.res.in

VISITING PROFESSORS

1. Prof. M. K. Mathew
   Tata Institute of Fundamental Research (TIFR), National Centre for Biological Sciences (NCBS), Bangalore
   e-mail: mathew@ncbs.res.in

2. Prof. K. Veluthambi, FASc, FNA, FNASc
   Formerly Head, Department of Plant Biotechnology
   School of Biotechnology, Madurai Kamaraj University (MKU), Madurai
   e-mail: kveluthambi@rediffmail.com

LABORATORY COORDINATORS

1. O. Thomas – School of Chemistry
   e-mail: othomas@iisertvm.ac.in Tel: 0471-2597437

2. Dr. T. Ganga Devi – School of Biology
   e-mail: gangadevi@iisertvm.ac.in

Administration

1. Prof. V. Ramakrishnan
   `Director`
   e-mail: director@iisertvm.ac.in Tel: 0471-2597421

2. Mr. M. Radhakrishnan
   `Registrar`
   e-mail: registrar@iisertvm.ac.in Tel: 0471-2597459

3. Mr. G. R. Giridharan
   `Deputy Registrar (F&A)`
   e-mail: drfa@iisertvm.ac.in Tel: 0471-2924815

4. Mr. B. V. Ramesh
   `Assistant Registrar (F&A)`
   e-mail: ramesh@iisertvm.ac.in Tel: 0471-2597422

5. Mr. S. Hariharakrishnan
   `Assistant Registrar (A&A)`
   e-mail: hariharan@iisertvm.ac.in Tel: 0471-2599408

6. Dr. Sainul Abideen P.
   `Assistant Librarian`
   e-mail: sainul@iisertvm.ac.in Tel: 0471-2599400

7. Dr. Goldwin Hemalatha M.
   `Medical Officer`
   e-mail: mo.hemalatha@iisertvm.ac.in Mob: 09447733335

8. Dr. Thiraviam P.
   `Medical Officer`
   e-mail: mo.thiraviam@iisertvm.ac.in

9. Mr. Sreekumar P. Y.
   `Scientific Officer (IT)`
   e-mail: sreekumarpy@iisertvm.ac.in Tel: 0471-2597422

10. Mr. Karthikeyan C.
    Security Officer
    e-mail: karthikeyan@iisertvm.ac.in Mob: 08547885654

11. Mr. Satya Srinivas Naraharisetti
    Superintendent (Hostel & Hospitality)
    e-mail: satya@iisertvm.ac.in

12. Mr. Manoj Kumar S.
    Superintendent (Office)
    e-mail: mano459@iisertvm.ac.in

13. Mr. Hariharan S.
    Superintendent (Facilities & Services)
    e-mail: harinair@iisertvm.ac.in

Academic Calendar

July	August	September	October	November	December
1 Tue	1 Fri Regn: S1, New I.Ph.D.; Regular Classes: S3-S9	1 Mon 1st Mid Sem	1 Wed	1 Sat	1 Mon Remedial Classes Start: S1 & S3
2 Wed	2 Sat Regn: S1, Orientation: S1	2 Tue 1st Mid Sem	2 Thu Gandhi Jayanti	2 Sun	2 Tue
3 Thu	3 Sun	3 Wed	3 Fri Dussehra	3 Mon	3 Wed
4 Fri	4 Mon Orientation: Ph.D. & IPh.D. Bridge Course Start: S1	4 Thu	4 Sat	4 Tue Muharram	4 Thu
5 Sat	5 Tue	5 Fri	5 Sun	5 Wed	5 Fri Last day for Submission of Marks & Grades
6 Sun	6 Wed	6 Sat	6 Mon Bakrid	6 Thu Guru Nanak Jayanti	6 Sat
7 Mon	7 Thu Bridge Course Ends: S1	7 Sun	7 Tue	7 Fri	7 Sun
8 Tue	8 Fri Regular Classes: S1	8 Mon	8 Wed	8 Sat	8 Mon
9 Wed	9 Sat	9 Tue	9 Thu	9 Sun	9 Tue Class Committee Meeting: S1-S9
10 Thu	10 Sun	10 Wed	10 Fri 2nd Mid Sem	10 Mon	10 Wed Publication of Results
11 Fri	11 Mon	11 Thu	11 Sat 2nd Mid Sem	11 Tue	11 Thu Remedial Classes End
12 Sat	12 Tue	12 Fri	12 Sun	12 Wed	12 Fri Repeat Exams Begin: S1-S9
13 Sun	13 Wed	13 Sat	13 Mon 2nd Mid Sem	13 Thu	13 Sat
14 Mon	14 Thu	14 Sun	14 Tue	14 Fri S3-S9: Classes End; Course Feedback Regular Classes: S1	14 Sun
15 Tue	15 Fri Independence Day	15 Mon	15 Wed	15 Sat	15 Mon
16 Wed	16 Sat	16 Tue	16 Thu	16 Sun	16 Tue
17 Thu	17 Sun	17 Wed Submission of Marks	17 Fri	17 Mon S3-S9: Exams Begin	17 Wed Repeat Exams End: S1-S9
18 Fri	18 Mon Janmashtami	18 Thu	18 Sat	18 Tue	18 Thu
19 Sat	19 Tue	19 Fri Class Committee Meeting	19 Sun	19 Wed S1: Classes End; Course Feedback	19 Fri
20 Sun	20 Wed	20 Sat	20 Mon Submission of Marks	20 Thu S1: Exams Begin	20 Sat
21 Mon	21 Thu	21 Sun	21 Tue	21 Fri	21 Sun
22 Tue	22 Fri	22 Mon	22 Wed Class Committee Meeting	22 Sat	22 Mon
23 Wed	23 Sat	23 Tue	23 Thu Diwali	23 Sun	23 Tue Publication of Repeat Exam Results
24 Thu	24 Sun	24 Wed	24 Fri Annual Sports Begins	24 Mon	24 Wed
25 Fri	25 Mon	25 Thu	25 Sat Senate Meeting	25 Tue	25 Thu Christmas
26 Sat Senate Meeting	26 Tue	26 Fri	26 Sun Annual Sports Ends	26 Wed	26 Fri
27 Sun	27 Wed	27 Sat	27 Mon	27 Thu S1-S9: Exams End	27 Sat
28 Mon	28 Thu	28 Sun	28 Tue	28 Fri Semester Ends	28 Sun
29 Tue Id-ul-Fitr	29 Fri Ganesh Chaturthi	29 Mon	29 Wed	29 Sat	29 Mon
30 Wed Regn: New Ph.D.	30 Sat 1st Mid Sem	30 Tue	30 Thu	30 Sun	30 Tue
31 Thu Regn: S1, S3-S9, Ph.D., IPh.D.	31 Sun		31 Fri		31 Wed

S1: Semester 1 for BS-MS