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 BS-MS DUAL DEGREE PROGRAMME

2013-14

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, Physics, Mathematics and other Interdisciplinary Science subjects.

The five IISERs established by MHRD are at Bhopal, Kolkata, Mohali, Pune 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 permanent campus of IISER TVM is coming up at Vithura, about 40 km from Thiruvananthapuram City, at the foothills of the Ponmudi Hills.

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Regulations

The BS-MS Programme

IISER-TVM is set up to provide education and perform research in diverse disciplines of basic sciences. The IISER-TVM BS-MS dual degree curriculum is designed to reflect the point of view that the sciences are a seamless whole with no barriers between disciplines.

- The BS-MS programme is of 10 semesters duration.
- Each academic year has 2 semesters of roughly 17 weeks each.

  (a) Varsha Semester : August – December.
  (b) Vasanth Semester : January – May.

- The first two years (i.e. the first 4 semesters) will consist of CORE courses common to all students.
- 3^{rd} and 4^{th} year courses will be specialized in one *major* (Biology, Chemistry, Mathematics or Physics). A student may choose to take courses that lead to a *minor(s)* in another subject(s).
- The 5^{th} year will be devoted to a thesis by research.
- Students may undertake summer research projects at IISERs and other institutions.

Registration

- Every student must register for the courses of a semester on the first day (registration day) of the semester.
- Registration involves payment of the prescribed fees for the semester.
- 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.

Faculty Adviser

Every student is assigned a Faculty Adviser who will guide the student in all academic and personal matters.

Assessment and Grading

Continuous Assessment

Continuous assessment will be adopted for all courses.

Theory Course :

Assignments	: 10%
Two Mid Semester Examinations	: 20 % each
End Semester Examination	: 50 %

Practical Course :

80 % weightage will be given for experiments through a continuous evaluation (contribution from experiments as well as viva during the practical hours). Experiments will be given equal weightage and marks will be given on the same day which will also be recorded in the lab note books of students. 20 % weightage will be given for written/viva examinations 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
I	Incomplete

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

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

Where, C_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:

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

Where, C_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*.

Degree Requirements

- Each student should acquire a minimum of 175 credits with a CGPA of 5.0 or greater for being eligible for the BS-MS dual degree.
- ALL CORE courses of the first two years must be successfully completed.
- All 3rd and 4th year courses designated as CORE by the school of the students' major has to be successfully completed.
- Successful completion of the major project is mandatory for the award of the BS-MS dual degree.

Essentials for Completing Courses

- Students are expected to attend all the classes. Students with overall 80% attendance will only be permitted to write the end semester examination. Attendance will be recorded in the prescribed book in every class and attendance grade will appear in the grade transcript.
- 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.
- I grades will be given to the students who miss the end semester examinations due to genuine reasons (e.g. serious medical reasons) as determined by the course instructor and the BS-MS coordinator and approved by the Dean (Academics) and Director. Make-up examination will be given to these students. The actual grade obtained after the make-up examination will be taken and will reflect in the transcript replacing the I grade.

  If the absence of a student in an examination is not approved by the Dean (Academics) and Director (e.g. a deliberate attempt to skip the examination), he/she will be awarded zero in that particular course examination. The final grade in that course will be determined based on the other course examinations taken by the student.
- If a student is permitted/asked to repeat a course in which he/she has been awarded an I grade (e.g. dropping a semester due to prolonged

illness), then the new grade obtained by the student will be taken into consideration and appear in the transcript. However, the previous I grade will also appear in the transcript, but will *not* contribute in calculation of CGPA.

- If a student does not clear a CORE course even after writing the repeat final examination, he/she is required to repeat the course with the same course number when offered next taking all examinations. Until the course is repeated and cleared by the student, it is treated as a *backlog* in the student's records. Both the new grade and the previous F grade obtained by the student will reflect in his/her transcript and contribute in the calculation of CGPA.

- Repeat of a course is not permitted if the student has obtained a grade D or above in the same course.
- A maximum of two backlog courses from the first two years MAY BE allowed, at the discretion of the Dean (Academics) and the Director, before a student can choose a major and proceed to the third year. However, the student will not be allowed to choose the subject(s) in which he/she has a backlog course(s) as his/her major.
- A student who has more than two F and/or I grades in a particular semester of the *first four semesters* will have to repeat ALL the courses of that semester. Only the new grades obtained in ALL the courses will be taken into consideration and the previous grades will be converted to I grades.

Ceiling of Credits in a Semester 5 - 8

A student of semesters 5-7 can register for a maximum of 21 credits in each semester. A student opting for a minor project (6 credits) in semester 8 can register for a maximum of 18 credits (including the minor project credits). However, students who are not opting for minor project can register up to 21 credits in semester 8.

Students should discuss with their faculty advisor and school coordinator (in which they are majoring) regarding registration of suitable courses at the beginning of each semester. This will help the students to avoid

unwanted complications at the end, e.g., fulfilling major/minor credit requirements and graduation requirements etc.

Removal from the Rolls

- Failure to maintain the minimum CGPA of 4.0 in any two consecutive semesters will lead to automatic removal of the student from the rolls.
- Failure to clear any CORE course even after repeating the same course will lead to the removal of the student from the BS-MS Programme.
- ALL CORE courses of the first two years must be completed in a maximum of six semesters. Failure to do so will lead to the removal of the student from the BS-MS programme
- All requirements for the BS-MS degree must be completed in a maximum of FOURTEEN SEMESTERS. Students will be automatically removed from the rolls at the end of fourteen semesters.

INSPIRE/KVPY Fellowship

The Department of Science and Technology Government of India has instituted the INSPIRE Fellowship available to each student of IISER. This provides Rs. 5,000/- per month stipend and Rs. 20,000/- for mentoring institutions and for doing summer projects.

The INSPIRE/KVPY fellowship is contingent upon good performance in each semester with a minimum AGPA (Annual Grade Point Average) of 6.0. If the AGPA falls below 6.0, the stipend will be stopped and can be restarted only when the AGPA goes to 6.0 or above.

MOODLE and Course Feedback

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

Online course feedback by students will be taken with full confidentiality for every course.

Revaluation of End Semester Examination Answer Sheets

Request for revaluation of answer sheets should be given by the student within 7 days of commencement of the next semester as a written request to the Academic Office and by paying a prescribed fee as revaluation charges.

Project Evaluation

- The major project work is carried out in two stages, each spread over a semester. At the end of nineth semester, the student is required to submit a preliminary brief report of his/her work by a prescribed date to the Project Coordinator and present it to an Internal Project Evaluation Committee as a seminar. Out of total 9 credits, 30% of weightage comes from Project guide and the remaining 70% is awarded by the Project Evaluation Committee(PEC). The second stage of the work is continued in the following semester and a final report has to be submitted at the end of tenth semester. The second part carries 15 credits and the distribution of scheme of evaluation will be same as mentioned above.
- PEC is constituted by School and the project co-ordinator will submit to the academic section the names of the project examiners at least two weeks before the submission of the second stage project. The project report, prepared according to the prescribed format available in the academic section, will be submitted to the School at least one week before the probable date of oral examination. The oral examination will be held before semester vacation starts. The whole evaluation process should be completed by a deadline stipulated by the academic session.
- The School will record the date of submission of the project and arrange to send the project reports to the examiners. The project coordinator will inform the date of the oral examination to the examiners and send a copy to the academic section. The project will be evaluated by the Project Evaluation Committee and the result will be submitted to the Project Coordinator, who in turn will forward it to the Academic Section.

- On successful completion of the oral examination, each student will be required to submit one corrected bound copy and a soft copy of the project report to the School/ supervisor(s).
- Extension of time usually not exceeding 3 months from the announced last date for submission of the project report may be granted by the School with permission of Dean/Director in the case of students with insufficient progress in the project work. In such a case the concerned students will be temporarily awarded 'I' grade. Further, if the reports are not submitted within the allowed period of time, the 'I' grade will be automatically converted to 'F' grade.
- Those who fail in the first stage assessment will be required to re-register for the first stage in the following semester. Likewise, those who obtain an 'F' grade in the final (second stage) assessment will be required to re-register for it in the subsequent semester.
- The one semester six credit minor project evaluation will also be carried out in a similar manner as mentioned above and the evaluation process has to be completed by the end of the semester as stipulated by the academic section. The evaluation has the following weightage: Project Guide:- 30% and PEC - 70%. The rules for submitting the final minor project report remain same like final major project report.

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

BS-MS Dual Degree in Science

Name of Student: **xxxx**
Batch Name: **Batch xxxx**
Roll Number: **IMS0XXXX**

Grades for Varsha xxxx*

COURSE NAME	COURSE CODE	COURSE CREDIT	MAX POINTS	LETTER GRADE OBTAINED	GRADE POINTS OBTAINED	ATTENDANCE MAX 10
Introductory Biology	BIO 111	3	30	B^+	24	8.5
Atomic Structure & Chemical Bonding	CHY 111	3	30	C^+	18	8.0
Introduction to Algebra	MAT 111	3	30	D	12	8.8
Mechanics	PHY 111	3	30	D	12	8.0
Mathematical Tools-I	IDC 111	3	30	B^+	24	8.9
Communication Skills	HUM 111	1	10	A^+	10	9.0
Biology Lab - I	BIO 112	1	10	A	10	10
Chemistry Lab - I	CHY 112	1	10	B^+	8	10
Physics Lab - I	PHY 112	1	10	B	8	10
TOTAL		19	190		126	

Semester Grade Point Average: **6.63**

Cumulative Grade Point Average: **6.63**

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, ~~M = Medical Leave~~

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.

Disciplinary Action for Academic Dishonesty:

1. **Disciplinary Action for Malpractices in Course Examinations:**

   If a student is found guilty of academic malpractice during the Mid-semester / Final examination of Theory / Laboratory / Computer courses, the following graded penalty may be recommended.

Sl. No.	NATURE OF MALPRACTICE	RECOMMENDED PENALTY
I.	Communicating with other student(s) inside the examination hall *or* Discussing with other student(s) outside the examination hall while the examination is in progress	*The erring student(s) shall be awarded one grade less in the subject concerned*
II.	Copying from another student's answer paper *or* Helping another student(s) to copy *or* Possessing the answer paper of another student *or* Passing an answer book to another student *or* Exchange of question papers with some answers written down on it	*The erring student(s) shall be awarded "I" grade in the subject concerned*
III.	Possessing/consulting incriminating* materials inside/outside the examination hall while the examination is in progress	*The erring student(s) shall be awarded "I" grade in the subject concerned and one grade less in all other subjects in the concerned semester*

Sl. No.	NATURE OF MALPRACTICE	RECOMMENDED PENALTY
IV.	Hacking/logging into other student's moodle account and copying in a computer course examination	*The erring student shall be awarded "I" grade in the subject concerned and one grade less in all other subjects in the concerned semester and all privileges related to usage of computer lab facility and/or Institute e-mail id shall be withdrawn for the subsequent semester*
V.	Involved in malpractice in an examination for the second time, in 'premeditated' manner	*The concerned student shall be awarded "I" grade in all courses being credited in that semester*
VI.	Involved in malpractice in an examination for the third time, in 'premeditated' manner	*Depending upon the seriousness of the malpractice and the previous records, the SDC of the Institute shall have the discretion to recommend one of the following actions: The concerned student shall be suspended for the concerned semester and the subsequent semester or Expulsion from the Institute*
VII.	Impersonation in the examination	*Expulsion from the Institute*

(*Incriminating materials include written/printed material; unauthorized additional sheets with or without write-ups, bits, scribbles on scales/handkerchief/on the body/on the desk/wall/floor, etc.; use of programming calculator/organizer/audio devices/electronic communication devices/storage devices or any other material that contains/transmits information).

- A student who has been awarded an "I" grade as a result of disciplinary action cannot seek repeat/make-up examination/special class in the subject(s) concerned. If a student is awarded "F" grade in certain course(s) due to the disciplinary action (by lowering one grade, as in cases I, III & IV in the above table), he/she may be allowed to take the repeat final examination.
- If a student is awarded an "I" grade in a particular course due to the disciplinary action, he/she needs to repeat the same course (in case of CORE course) whenever it will be offered or any other course (in case of minor/elective course).
- The above list of academic malpractices and ensuing penalties are representative; neither exhaustive nor limited to the above.
- The SDC may recommend an additional/alternate course of action/reformative action depending on the severity of the malpractice.

General Remarks for Awareness:

Students should be aware that the consequences of any disciplinary action could be non-uniform and in some cases could severely compromise one's academic career. IISER-TVM strongly encourages students to speak with their parents/guardians or consult faculty advisors regarding conduct matters. Lack of knowledge of the rules and regulations is not an excuse for misconduct/dishonesty and shall not be a basis for leniency in disciplinary matters.

i. If a student is found guilty in repeated/serious academic malpractices, the Institute may not recommend summer/winter projects outside the Institute. Moreover, the School/Institute may not issue good conduct certificate for him/her.
ii. If a student is found guilty of academic misconduct, after completion of graduation credit requirements, the Institute may withhold award of degree for a certain period, decided by the severity of the misconduct. The degree may be awarded at the end of the recommended withholding period provided the student does not again violate the Code of Conduct within that period.

2. **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 expulsion of the student.
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.
Plagiarism includes, without citation, the appropriation of another individual(s)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 and National Holiday: Closed
   b. During Exam Week: 9 AM to 10 PM.

c. Circulation of Books will be between 9.15 AM to 5.15 PM on Monday to Friday. On Saturdays Circulation of Books will be till 12 noon.

2. Membership: All BS-MS students are eligible for membership at the institute library.
3. Borrowing facility: BS-MS students can borrow a maximum of 4 books at a time for 2 weeks, provided they do not have any overdue book with them.
4. Users must leave their Bags and other belongings outside the Library. Only notebooks and papers are allowed inside the library. Issued books are allowed to be taken to the Library for return/renewal only. All items taken out of the library are to be produced for verification by the check point staff engaged in front of the Library.
5. Always carry the Identity card and must be produced whenever asked for.Identity card is mandatory to for borrowing books from the Library.
6. Silence has to be maintained by all users in the Library.
7. Use of Mobile Phones, consumption of food and drinks are strictly prohibited inside the Library.
8. Use of Laptop is allowed only for accessing e-journals, e-books and academic databases only.
9. Return of book is mandatory before the due date. A fine of Re.1/- per day per book for the first week of delayed return and Rs.10/- per day per book thereafter will be levied. Renewal of a book is possible only if there is no pending reservation against it. A book may be recalled anytime before the due date, if it is urgently required by another member. A late fee of Rs.10/- per day per book will be imposed for the non-compliance with the requirement.
10. Reference books can be borrowed as overnight issue, at the closing time of the library and to be returned at 9 AM on the next working day. Only one book can be issued per user as overnight. A late fee of Re.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 found.

12. Members who lose/mutilate library materials are liable to replace the book with latest edition of the books along with a penalty of 20% of the total cost of the book. All books replaced in this manner must be of the latest edition. If the book is part of a set or series they may be called upon to replace the whole set or series. In case of the lost books is untraceable in market or out of print Library committee reserves the right to decide appropriate penalty.
13. BS-MS 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 to the library staff 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 BS-MS 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.
16. All the BS-MS students have to vacate the hostel during the vacation time. If any student wants to stay back during the vacation, special permission has to be obtained from the competent authority in advance.

Course Structure

The first two years of the BS-MS programme consists of FOUNDATION courses common to all students. Third and fourth year courses will be specialized in one major (Biology, Chemistry, Mathematics or Physics) and one or more minors. The fifth year will be devoted to a thesis by research. The general structure of the BS-MS course is given below.

BS-MS Course Structure

Sl. No.	Course Description	Minimum Credits	Period
1	Foundation Courses	76	Semester I to IV
2	Major Courses	57	Semester V to X
3	Major Project	24	Semester IX to X
4	Minor Courses	9	Semester V to VIII
5	Minor Project	6	Semester VIII
6	Humanities/Additional courses	3	Semester V to X
Total		175	

Remark: *Minor project is optional in certain schools. However, students may adjust this credit by taking additional courses.*

Course Codes

The or FOUNDATION and CORE courses are numbered in the format,

XYZ LSC (LTPC)

The ELECTIVE courses are numbered in the format,

XYZ LSCD (LTPC)

The numbering may be understood as

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

Subject codes

BIO : Biological Sciences
MAT : Mathematical Sciences
IDC : Interdisciplinary Studies
CHY : Chemical Sciences
PHY : Physical Sciences
HUM : Humanities

First Four Semesters

FOUNDATION COURSES FOR THE FIRST TWO YEARS (4 SEMESTERS)

Semester I						Semester II					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 111	Introductory Biology	3	1	0	3	BIO 121	Introductory Physiology	3	1	0	3
CHY 111	Atomic Structure & Chemical Bonding	3	1	0	3	CHY 121	Chemistry of Elements	3	1	0	3
MAT 111	Introduction to Algebra	3	1	0	3	MAT 121	Introductory Analysis I	3	1	0	3
PHY 111	Mechanics	3	1	0	3	PHY 121	Electromagnetism	3	1	0	3
IDC 111	Mathematical Tools I	2	0	2	3	IDC 121	Mathematical Tools II	2	0	2	3
HUM 111	Communication Skills	0	1	0	1	HUM 121	Humanities	0	1	0	1
BIO 112	Introductory Biology Lab	0	0	3	1	BIO 122	Physiology Lab	0	0	3	1
CHY 112	Chemistry Lab I	0	0	3	1	CHY 122	Chemistry Lab II	0	0	3	1
PHY 112	Physics Lab I	0	0	3	1	PHY 122	Physics Lab II	0	0	3	1
Total		**14**	**5**	**11**	**19**	**Total**		**14**	**5**	**11**	**19**
Cumulative Credits at the End of First Year: 38											
Semester III						**Semester IV**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 211	Ecology Evolution and Behaviour	3	1	0	3	BIO 221	Genetics and Molecular Biology	3	1	0	3
CHY 211	Chemical Reactions & Reactive Intermediates	3	1	0	3	CHY 221	Principles of Physical Chemistry	3	1	0	3
MAT 211	Introductory Analysis II	3	1	0	3	MAT 221	Introduction to Statistics	3	1	0	3
PHY 211	Optics	3	1	0	3	PHY 221	Thermal &Statistical Physics	3	1	0	3
IDC 211	Biochemistry	3	1	0	3	IDC 221	Principles & Appl. of Spectroscopy	3	1	0	3
HUM 211	Humanities	0	1	0	1	HUM 221	Humanities	0	1	0	1
BIO 212	Ecology, Evolution and Behaviour Lab	0	0	3	1	BIO 222	Genetics and Molecular Biology Lab	0	0	3	1
CHY 212	Chemistry Lab III	0	0	3	1	CHY 222	Chemistry Lab IV	0	0	3	1
PHY 212	Physics Lab III	0	0	3	1	PHY 222	Physics Lab IV	0	0	3	1
Total		**15**	**6**	**9**	**19**	**Total**		**14**	**6**	**9**	**19**
Cumulative Credits at the End of Second Year: 72 (Foundation Courses)* + 1 (Communication Skills)* + 3 (Humanities)**											

* Essential courses of semester 1-4

** Humanities will be offered between semesters 1-6

Semesters 5 to 10

Major and Minor Courses

Every student is allowed to choose a major subject. The available majors are in Biology, Chemistry, Mathematics and Physics. Number of seats in each major subject is normally limited to 30%. The top 30%, in the order of merit, among the students who have chosen a particular major subject will be given preference. Each student has an option to choose one minor as well. Both choices will be reflected in the BS-MS degree certificate that will be awarded by IISER TVM on successful completion of the programme.

The minimum number of credits required to obtain a BS-MS degree from IISER TVM is 175. Out of this, 76 credits are carried by the common core courses taken by all students over the first two years.

A minimum of 57 credits from courses in the major subject and 9 credits from courses from non-major subjects taken during the 3^{rd}, 4^{th} and 5^{th} years are needed for graduation. Individual schools are free to place additional requirements for obtaining a major or minor in their respective disciplines. Schools will also specify how the credits are split between theory and laboratory courses.

The student may alternatively opt to have no minor, but takes the 9 course credits from more than one school excluding the school of his/her major.

In addition to the courses, each student will undertake a one year research project in his/her major subject worth 24 credits during the 5^{th} year. The 6 credit minor project undertaken by the student during the 8^{th} semester should be done in a school other than the school of his/her major. Minor project is optional in certain schools. In that case, students are required to take additional courses from non-major subjects to compensate the lost credit.

A course in humanities of the student's choice from among the available courses worth three credits will also have to be successfully completed for awarding the BS-MS degree.

A table outlining the course requirements (sample structure only) for the 3^{rd}, 4^{th} and 5^{th} years is given below. The total earned credits shown are minimum values. Individual schools may choose to offer more courses or courses that carry less/more credits than what is shown in the table.

Credits earned from the first two years: 76

Third Year

SEMESTER 5

SL. NO.	COURSE	CREDITS	MAJOR CREDITS	MINOR CREDITS	TOTAL
1	Major 1	3	This Semester	This Semester	This Semester
2	Major 2	3	15	3	18
3	Major 3	3			
4	Major 4	3			
5	Major 5(Lab/Theory)	3	Cumulative	Cumulative	Cumulative
6	Minor 1	3	15	3	94

SEMESTER 6

SL. NO.	COURSE	CREDITS	MAJOR CREDITS	MINOR CREDITS	TOTAL
1	Major 1	3	This Semester	This Semester	This Semester
2	Major 2	3	15	3	18
3	Major 3	3			
4	Major 4	3			
5	Major 5 (Lab/Theory)	3	Cumulative	Cumulative	Cumulative
6	Minor 1	3	30	6	112

Fourth Year

SEMESTER 7

SL. NO.	COURSE	CREDITS	MAJOR CREDITS	MINOR CREDITS	TOTAL
1	Major 1	3	This Semester	This Semester	This Semester
2	Major 2	3	12	3	18
3	Major 3	3			
4	Major 4 (Lab/Theory)	3			
5	Minor 1	3	Cumulative	Cumulative	Cumulative
6	Humanities	3	42	9	130

SEMESTER 8

SL. NO.	COURSE	CREDITS	MAJOR CREDITS	MINOR CREDITS	TOTAL
1	Major 1	3	This Semester	This Semester	This Semester
2	Major 2	3	12	6	18
3	Major 3 (Elective)	3			
4	Major 4 (Lab/Theory)	3	Cumulative	Cumulative	Cumulative
5	Project (Minor)	6	54	15	148

Fifth year

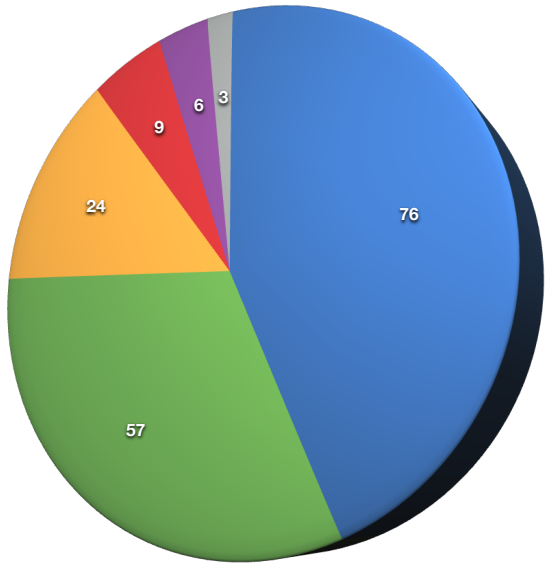
SEMESTER 9

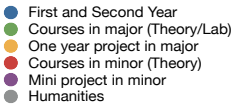
SL. NO.	COURSE	CREDITS	MAJOR CREDITS	MINOR CREDITS	TOTAL
1	Major 1 (Elective)	3	This Semester 12	This Semester 0	This Semester 12
2	Major Project and Seminar-I	9	Cumulative 66	Cumulative 12	Cumulative 160

SEMESTER 10

SL. NO.	COURSE	CREDITS	MAJOR CREDITS	MINOR CREDITS	TOTAL
1	Major Project and Seminar-II(Final Project Report)	15	This Semester 15 Cumulative 81	This Semester 0 Cumulative 15	This Semester 15 Cumulative 175

Distribution of Credits





Biology Major

MAJOR IN BIOLOGY (THIRD YEAR TO FIFTH YEAR)

Semester V						Semester VI					
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 Third Year: 106											
Semester VII						**Semester VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 411	Developmental Biology	3	0	0	3	BIO 421	Mathematical & Systems Biology	3	0	0	3
BIO 412	Biostatistics	3	0	0	3	BIO 422	Advanced Physiology	3	0	0	3
BIO 413	Plant Molecular Genetics	3	0	0	3	BIO 423	Advanced Molecular Biology	3	0	0	3
BIO 414	Genomics	3	0	0	3	BIO 4201	Elective I	3	0	0	3
BIO 415	Advanced Biology Lab III	0	0	9	3						
Total		**12**	**0**	**0**	**15**	**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 133											
Semester IX						**Semester X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 511	Major Project	9	0	0	9	BIO 521	Major Project	15	0	0	15
BIO 5101	Elective II	3	0	0	3						
Total		**12**	**0**	**0**	**12**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 160											

Remark: *To meet the minimum requirement of 175 credits for qualifying the BS-MS Degree, students may take minor or additional courses.*

Chemistry Major

MAJOR IN CHEMISTRY (THIRD YEAR TO FIFTH YEAR)

Semester V						Semester VI					
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	Organometallic 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 Third Year: 107											
Semester VII						**Semester VIII**					
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 421	Electrochemistry	3	0	0	3
CHY 412	Advanced Chemical Kinetics	3	0	0	3	CHY 422	Physical Organic Chemistry	3	0	0	3
CHY 413	Advanced Organic Chemistry II	3	0	0	3	CHY 423	Advanced Organic Chemistry III	3	0	0	3
CHY 414	Bioinorganic Chemistry	3	0	0	3	CHY 4201	Elective I	3	0	0	3
CHY 415	Advanced Physical Chemistry Lab	0	0	9	3						
Total		**12**	**0**	**9**	**15**	**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 134											
Semester IX						**Semester X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
CHY 511	Major Project	9	0	0	9	CHY 521	Major Project	15	0	0	15
CHY 5101	Elective II	3	0	0	3						
Total		**12**	**0**	**0**	**12**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 161											

Remark: *To meet the minimum requirement of 175 credits for qualifying the BS-MS Degree, students may take minor or additional courses.*

Mathematics Major

MAJOR IN MATHEMATICS (THIRD YEAR TO FIFTH YEAR)

Semester V						Semester VI					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
MAT 311	Real Analysis	3	0	0	3	MAT 321	Complex Analysis	3	0	0	3
MAT 312	Discrete Mathematics	3	0	0	3	MAT 322	Measure Theory and Integration	3	0	0	3
MAT 313	Abstract Algebra	3	0	0	3	MAT 323	Galois Theory & Commutative Algebra	3	0	0	3
MAT 314	Advanced Linear Algebra	3	0	0	3	MAT 324	Multivariate Analysis	3	0	0	3
MAT 315	Numerical Analysis	3	0	0	3	MAT 325	General Topology	3	0	0	3
MAT 3101	Elective I - Operation Research	3	0	0	3						
Total		**18**	**0**	**0**	**18**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Third Year: 109											
Semester VII						**Semester VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
MAT 411	Functional Analysis	3	0	0	3	MAT 421	Advanced Analysis	3	0	0	3
MAT 412	Probability Theory & Random Processes	3	0	0	3	MAT 422	Partial Differential Equations	3	0	0	3
MAT 413	Number Theory and Cryptography	3	0	0	3	MAT 423	Combinatorics & Graph Theory	3	0	0	3
MAT 414	Theory of Ordinary Differential Equations	3	0	0	3	MAT 424	Differential Geometry	3	0	0	3
MAT 415	Reading Seminar	0	0	3	1	MAT 4201	Elective III*	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: 140											
Semester IX						**Semester X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
MAT 511	Major Project	9	0	0	9	MAT 521	Major Project	15	0	0	15
MAT 5101	Elective IV	3	0	0	3						
MAT 5102	Elective V	3	0	0	3						
Total		**15**	**0**	**0**	**15**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 170											

**Students opting for minor project in the 8th semester will not be allowed to credit Elective III due to the restriction in registration of credit limit, which is 18 credits including minor project.*

Remark 1: *The school is not obliged to offer an elective in a particular semester if situation warrants.*
Remark 2: *To meet the minimum requirement of 175 credits for qualifying the BS-MS Degree, students may take minor or additional courses.*
Remark 3: *The electives MAT 3101/ MAT 4101 will be offered in every alternate year.*

Physics Major

MAJOR IN PHYSICS (THIRD YEAR TO FIFTH YEAR)

Semester V						Semester VI					
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
Total		**12**	**0**	**9**	**15**	**Total**		**12**	**0**	**9**	**15**
Cumulative Credits at the End of Third Year: 106											
Semester VII						**Semester VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
PHY 411	Experimental Methods	3	0	0	3	PHY 421	High Energy Physics	3	0	0	3
PHY 412	Condensed Matter II	3	0	0	3	PHY 422	Atomics & Molecular Physics	3	0	0	3
PHY 413	Quantum Mechanics II	3	0	0	3	PHY 423	Computational Techniques & Programming Language	3	0	0	3
PHY 414	Elective I	3	0	0	3	PHY 4201	Elective II	3	0	0	3
PHY 415	Advanced Physics Experiments Lab III	0	0	9	3						
PHY 416	Workshop & Engineering Drawing	0	0	3	1						
Total		**12**	**0**	**12**	**16**	**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 134											
Semester IX						**Semester X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
PHY 511	Major Project	9	0	0	9	PHY 521	Major Project	15	0	0	15
PHY 5101	Elective III	3	0	0	3						
Total		**12**	**0**	**0**	**12**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 161											

Remark: *To meet the minimum requirement of 175 credits for qualifying the BS-MS Degree, students may take minor or additional courses.*

Choice Form

At the end of the fourth semester, the students make their choice regarding the major and minor subjects. The following choice form is to be filled up and submitted to the Academic Office. The major subject will usually be allotted based on the student's CGPA and performance in that subject in the first four semesters. The Academic Office will arrange counselling session involving students and concerned members of the faculty before finalizing the allotment of major.

INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH THIRUVANANTHAPURAM

Academic Office

Application form for choosing Major

1 Name: _____

2 Roll No: _____

3 Whether all courses up to 3rd sem are cleared in the first attempt. If No, list those courses. _____

4 **Choice of Major**: Subject GPA and CGPA up to 3rd Sem. For eg., **Subject GPA** is calculated as follows. If MAT 111 – A+ MAT 121 –B+; MAT 211 – B+; Maths GPA= (3*10+ 3*8+3*8)/(3+3+3) = 8.67(corrected up to 2 dec.)
Index Point = 0.5*(Subject GPA + CGPA)

Choice in order of Preference	Major Subject	Sem-I Grade		Sem-II Grade		Sem-III Grade		Subject GPA	CGPA up to 3rd Sem	Index Point
		Theory	Lab	Theory	Lab	Theory	Lab			
First Choice										
Second Choice										
Third Choice										
Fourth Choice										

5 Choice of Minor, if any, in order of preference(Optional)
1 _____
2 _____

Declaration:

I hereby declare that the details furnished in the application are true and agree to the allotment of major based on my preferences and academic standing.

Date : _____ (Signature of the Student)

Biology Syllabus

THEORY COURSES

BIO 111 Introductory Biology [3103]

Introduction to biology: What is life? The basic unit of life "The Cell", Variety of shapes and functions of Cells, Structures within cells that carry out the functions of cells (organelles), Multicellularity and Multicellular organisms.

The molecules of life (biological macromolecules): Nucleic Acids, Proteins, Carbohydrates, Lipids; Molecular census.

Central dogma of life: Basics of DNA replication, Transcription, Translation.

Time Scales in Biology: Procedural Time: processes of Central Dogma, Clocks & Oscillators; Relative Time: cell cycle and checkpoints, formation of bacterial flagellum, Development; Manipulated Time: chemical kinetics and enzyme turnover, diffusion and molecular motors, Membrane Proteins and Transmembrane Transport.

Introduction to model systems: Haemoglobin as a model protein; Bacteriophage & Molecular Biology: Delbruck-Luria and fluctuation test, Hershey-Chase experiments; *E. coli* (Meselson-Stahl experiments on semi-conservative replication, bacterial chemotaxis); Yeast (rise of biochemistry); Flies (Drosophila and Modern Genetics, Homeotic mutations); Mice, Arabidopsis & Men; Exotica (Squid Axon, C. elegans).

Hierarchical levels of organization in Biology: Shapes and sizes of life forms, comparative organization of life forms, variation and diversity of life viruses bacteria, protists, fungi, plants and animals.

BIO 121 Introductory Physiology [3103]

Introduction to plant biology; vegetative and reproductive anatomy; economic importance of plant parts - roots, stems, leaves, flower and seeds as food, feed, fibre, fuel and medicine.

Plant water and mineral nutrition: uptake, translocation of water, ions, solutes and other macromolecules through xylem and phloem; transpiration and mechanisms of loading and unloading of photoassimilates.

Introduction to photosynthesis and carbon dioxide fixation: light dependent and independent reactions, introduction to C3, C4 and CAM pathways.

Introduction to phytohormones and its role in plant physiological process and development.

Introduction to senescence and programmed cell death in plants Plant symbiosis: bacteria and fungal plant symbiosis, biological nitrogen fixation.

Fundamentals of animal physiology; Animals and their environment; Cells and molecules in animal physiology.

Introduction to physiological processes: neural functions, senses, communication, feeding and digestion, movement, respiration, circulation, excretion.

BIO 211 Ecology, Evolution and Behaviour [3103]

Overview: The science of ecology and evolution.

Principles of Ecology: Distribution of living things (role of abiotic factors, global climate patterns, biomes and biogeographic realms); Ecosystem ecology (food webs, biogeochemical cycles, energy flow); Community ecology (ecological Succession, microhabitats, island biogeography); Ecological niches; Population ecology (population characteristics, growth, metapopulations); Species interactions (antagonistic and mutualistic interactions).

Principles of Evolutionary Biology: History of Evolutionary thought; Fundamental concepts (variation, selection, units of selection, adaptation); Evolution of population structure (population genetics, HW Equilibrium); Genetic drift; Species (concepts, speciation); Introduction to Macroevolution; History of life on earth (phylogenetics, tree of life, convergent evolution, systematics, fossil record, key events, historical biogeography); Adaptive radiations; Pattern and process in macroevolution (rates of evolution, punctuated equilibrium, gradualism, saltation, phylogenetic conservatism etc.).

Behavioral ecology: Adaptive value of behaviour; Sexual selection; Sociality (altruism, cooperation, kin selection, etc.); Game theory; Optimal foraging theory; Mating systems, parental care, alternate breeding systems.

Biodiversity and Conservation Biology: Biodiversity: key concepts; Measuring diversity; Origination of biodiversity and extinctions; Global change; Conservation Ecology (conservation genetics, wildlife management, in-situ and ex-situ conservation, invasive species).

BIO 221 Genetics and Molecular Biology [3103]

Introduction to genetics.

Mendelian genetics: Mendal's law and examples, Monohybrid and dihybrid cross, recessive and dominant mutation, concept of allele.

Non-Mendelian genetics: incomplete dominance, semi-dominance, and introduction to epigenetics, infection heredity.

Genetic interactions: approach towards generating a network (epistasis, redundancy, synthetic lethality, lethal interactions).

Model organisms and studies on molecular and genetic interactions.

Tools to study genetics: forward genetics (map based cloning), reverse genetics (RNA interference), transcription, translation and spatiotemporal regulation of gene expression.

Genome composition: organization of the genome, coding and non-coding sequences, regulatory elements, repeat sequences, transposons, organelle genomes.

Chromosome structure and function: packaging of DNA into nucleosomes, basic chromosome features-centromeres, telomeres and their functions, chromosome segregation in mitosis and meiosis.

DNA replication: DNA polymerases, mechanism of replication, replication of damaged DNA, termination.

Mutations: sources of mutations, types of mutational events, Methods to detect mutations, mutations and disease.

DNA repair: DNA damage response, direct repair, base excision repair, nucleotide excision repair, mismatch repair, double strand break repair.

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 interactions 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 ma-

trices -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 electrophoresis (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 polarity.

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

BIO 421 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 422 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 alkaloids 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 423 Advances in Molecular Biology [3003]

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

Molecular aspects of replication, RNA processing, transcription and trans-

lation.

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.

Partial List of 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 112 Introductory Biology [0031]

1. Plant cell under a microscope
2. Animal cell under a microscope
3. Structure and function of plant tissues and their function
4. Staining and differential staining of bacteria
5. Bacterial mobility - Hanging drop method
6. Staining and visualizing yeast cells
7. Determination of blood groups
8. Preparation of blood smear
9. Mitosis
10. Meiosis

11. Microsporogenesis and megasporogenesis
12. Isolation of amylase enzymes from germinating seeds

BIO 122 Physiology [0031]

1. Measurement of water potential, relative water content in plants
2. Estimation of chlorophyll and anthocyanin content in plants, photosynthetic efficiency in plants
3. Estimation of phenolics, tannins in plants
4. Estimation of HCN content in Tapioca plants
5. Diagnosis of plant mineral nutrient deficiency in plants
6. Measurement of feeding rates
7. Measuring growth and fecundity in varying nutrient environments
8. Glucose and lipid estimation in fed and starved conditions
9. Assaying olfactory and gustatory responses
10. Examining muscular system and muscle defects
11. Analysis of Brain structures and neuronal functions

BIO 212 Ecology, Evolution and Behaviour [0031]

1. Plant group study - Hydrophytes, Xerophytes, Epiphytes, Parasites, Mesophytes using T.S of stem and leaves
2. Water sample analysis
3. Isolation of nodule bacteria
4. Rhizosphere analysis
5. Short duration lab and field projects
6. Experimental design in ecology

BIO 222 Genetics and Molecular Biology [0031]

1. Preparation of buffer and ph measurement
2. Plasmid isolation
3. Agarose gel electrophoresis of DNA
4. Transformation of Bacteria
5. Restriction digestion of Bacteria
6. Genomic DNA isolation

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 111 Atomic Structure and Chemical Bonding [3103]

Atomic Structure: Recap of dual nature of radiation and matter, introductory quantum mechanics for chemistry, quantization of energy and angular momentum, the Schrdinger equation, postulates of quantum theory, understanding of postulates via model problems, particle in a one dimensional box, particle in a ring and harmonic oscillator, probabilities and electron density, hydrogen atom, separation of variables, quantum numbers, orbitals and nodes.

Chemical Bonding: Molecular symmetry and group theory;General discussions on bonding, valence bond and molecular orbital theory, linear combination of atomic orbitals (LCAO) approach, molecular orbitals, normalization of molecular orbitals, overlap intergral, bonding and antibonding orbitals, Hckel model; Bonding in homonuclear diatomic systems, dihydrogen molecule-ion and dihydrogen molecule, homonuclear diatomic molecules of the second period, their energetics, bond orders, bond lengths and bond strengths, photoelectron spectra.

Bonding in heteronuclear diatomic molecules (selected ones), polar bonds, electronegativity, and variation principle; Bonding in triatomic and polyatomic molecules (selected ones);Bonding in transition metal complexes, valence bond theory, electroneutrality principle and back bonding, crystal field theory, octahedral and tetrahedral symmetry, crystal field stabilization energy, Jahn Teller theorem, ligand field and molecular orbital theories; Metallic and ionic bonding, weak bonds and supramolecular chemistry.

TEXTBOOKS/REFRENCES

1. P. W. Atkins and Julio de Paula, *Physical chemistry*, 8^{th} Ed., Oxford University Press.
2. D. A. McQuarrie, *Quantum chemistry*, 2^{nd} Ed.

3. J. Barrett, *Structure and bonding, Tutorial Chemistry Text*, Royal Society of Chemistry.
4. K. J. Laidler and J. H. Meiser, *Physical chemistry*, Indian Ed.

CHY 121 Chemistry of Elements [3103]

Qualitative aspects of hybridization, hybridized orbitals including those involving d-orbitals, molecular orbital theory (qualitative) and shapes of molecular orbitals, 3-center-2-electron bonds; Structures of elemental B and C, P and S, Fullerenes and graphene, structure and bonding of hydrides and halides of Be, B, and Al, boron nitrides, borazine, carbon nitrides, silicates, silicates with chain and sheet structures, zeolites, P-N compounds, structure and bonding in phosphonitrilic compounds, sulphur-nitrogen compounds, inter-halogen compounds.

Coordination compounds involving various transition metals, IUPAC nomenclature of coordination compounds, coordination compounds with octahedral, tetrahedral, square-planar, square pyramidal and trigonal-bipyramid geometries, isomerism in coordination compounds, lability, trans-effect, chelate effect, splitting of d-orbitals in various ligand fields, crystal field theory and calculation of CFSE of coordination compounds of various metal ions in diverse geometries, electronic spectra, color characteristics and magnetic properties of coordination compounds, spectrochemical series of ligands, low-spin and high-spin complexes, structural characterization of various metal complexes based on spectral and magnetic properties, Jahn-Teller theorem and its effect on structural features of coordination compounds.

Lanthanides and actinides, lanthanide contraction, coordination compounds involving lanthanides; Organometallic compounds, 18-electron rule, hapticity of ligands, structural prediction of complex organometallic compounds based on 18-electron rule, metal carbonyls, donor and acceptor properties of CO in metal carbonyls and bonding features, metal olefins and metallocenes, reactions involving organometallic compounds, organometallic compounds as catalysts; The role of coordination compounds in biological systems, haemoglobin, chlorophyll, metalloenzymes, metalloporphyrins, cis-platin.

TEXTBOOKS/REFRENCES

1. F. A. Cotton, G. Wilkinson and P. L. Gaus, *Basic Inorganic Chemistry*, 3^{rd} Ed. (1995).
2. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic Chemistry: Principles and Reactivity* 4^{th} Ed., Pearson Education, (2008).
3. P. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, *Shriver & Atkins Inorganic Chemistry* 4^{th} Ed., Oxford University Press (2008).
4. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models in Inorganic Chemistry* 3^{rd} Ed., Wiley (1994).
5. W. Kaim and B. Schwederski, *Bioinorganic chemistry: Inorganic Elements in the Chemistry of Life*, Wiley (2006).
6. W. K. Li, G. D. Zou and T. C. W. Mak, *Advanced Structural Inorganic Chemistry* Oxford Science Publication (2008).
7. W. W. Porterfield, *Inorganic Chemistry- A Unified Approach* 2^{nd} Ed., Academic Press (2008).
8. N. N. Greenwood and A. Earnshaw, *Chemistry of Elements* 2^{nd}.
9. J. E. House, *Inorganic Chemistry*, Academic Press, (2008).

CHY 211 Chemical Reactions and Reactive Intermediates [3103]

Reactive intermediates: Formation, structure, stability and fate of various reactive intermediates (carbanion, carbocation, carbenes, nitrenes, benzynes, free radicals); Nucleophilic substitution at saturated carbons (SN1, SN2 and SNi): Types, stereochemical consideration, role of solvent, NGP.

Electrophilic aromatic Substitution: Benzene and its reaction with electrophiles, Effect of functional groups; Nucleophilic aromatic substitution: Diazonium compounds, benzyne mechanism, Electrophilic addition to alkenes.

Elimination reactions: Types (E1, E2 and E1cB), stereochemical consideration, role of solvents, Hofmann rules, Zaytsev Rules, nucleophilic addition to the carbonyl group, nucleophilic substitution at the carbonyl group, radical reactions, reactive intermediates in biology and environment;

TEXTBOOKS/REFRENCES

1. R. T. Morrison and R. N. Boyd, *Organic Chemistry*, 6^{th} Ed., Prentice Hall (1992).
2. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic chemistry*, Oxford University Press (2000).
3. P. Sykes, *A guide book to Mechanism in organic chemistry*, Addison-Wesley (1996).
4. M. B. Smith and J. March, *Advanced Organic Chemistry: reactions, mechanism and Structures*, 6^{th} Ed., Wiley Interscience (2007).

5. F. A. Carey and R. J. Sundberg, *Advanced Organic Chemistry*, 6^{th} Ed., Springer (2007).

CHY 221 Principles of Physical Chemistry [3103]

Real gases: Molecular interactions, van der Waals equations, principle of corresponding states, fugacity and pressure; Molecular interactions: Electric dipole moment and molecular polarizability, interactions between molecules; Chemical thermodynamics: Overview of the laws of thermodynamics, concepts and applications; Thermodynamics of physical transformations: Phase boundaries, supercritical fluids, phase diagram of water and carbon dioxide, phase stability and transitions, Clausius-Clayperon equation, liquid-vapour interface (surface tension, curved surface and capillary action); Thermodynamic of Mixtures: Partial molar quantities and chemical potential, Gibbs-Duhem equation, thermodynamics of mixing, ideal solutions (Henry's and Raoult's law).

Properties of Solutions: Colligative properties (elevation of boiling point, depression of freezing point and osmotic pressure), binary solutions; Phase Diagrams: Phase rule and two component systems, vapour pressure diagram, temperature composition diagram, fractional, azeotropic and steam distillations and their importance in organic chemistry; Chemical Equilibrium: Chemical reactions and Gibbs energy, response of equilibria to various conditions, application to selected systems (extraction of metals from oxide and Ellingham diagram, acid-base systems and Henderson-Hasselbalch equation).

Electrochemistry: Thermodynamic properties of ions in solution, Debye-Hckel law, conductance and its applications, transport number, electrochemical cells, Nernst equation, standard electrode potential, electrochemical series, redox reactions in biology, EMF and free energy, determination of solubility constants, pH and pKa from EMF measurements, concentration cells with and without transference, ion pumps in biology, polarography, batteries and fuel cells.

Chemical Kinetics: Reactions of various orders, Arrhenius equation, collision theory, theory of absolute reaction rates, chain reactions, enzyme kinetics, fast reactions, photophysical and photochemical processes, catalysis and surface reactions.

TEXTBOOK

1. P. W. Atkins and Julio de Paula, *Physical chemistry*, 8^{th} Ed., Oxford University Press.
2. K. J. Laidler and J. H. Meiser, *Physical chemistry*, Indian Ed.

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/REFRENCES

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, Schrdinger 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, Hckel theory and applications across organic chemistry, tight-binding approximation, WKB, Krnig-Penney model, The extended Hckel 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/REFRENCES

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, chirality due to folding of helical structures.

Geometrical isomerism - E and Z notation of compounds with one and

more double bonds in acyclic systems, inter conversion of geometrical isomers, stereochemistry of other classes of double bonded systems, asymmetric synthesis, illustration with examples. Chiral auxiliaries and chiral reagents.

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

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

TEXTBOOKS/REFRENCES

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, ioniz-

ing 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/REFRENCES

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/REFRENCES

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

CHY 323 Advanced Organic Chemistry I [3003]

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

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

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

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

Stereoselective reactions of cyclic compounds: Stereochemical control in 6-membered ring, conformational control in the formation of 6-membered rings, sterochemistry of bicyclic compounds, fused bicyclic compounds, spirocyclic compounds, reactions with cyclic intermediates or cyclic TS. Diastereoselectivity: Steroeselectiv ereactions, prochirality, diasteroselctive

addition to carbonyl groups, chelation controlled stereoselectivity, steroselective reactions of scyclic alkenes, steroselective aldol reactions.

TEXTBOOKS/REFRENCES

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/REFRENCES

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/REFRENCES

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

SUGGESTED READING

1. R. Hoffmann, *Solids and Surfaces: A chemist's view of bonding in extended structures*, Wiley-VCH, 1988.
2. N. W. Ashcroft and N. D. Mermin, *Solid State Physics*, Brooks-Cole (1976).
3. S. Elliot, *The Physics and Chemistry of Solids*, Wiley India (1998).

CHY 412 Advanced Chemical Kinetics [3003]

Introductory kinetics: Determination of order of reaction, complex reactions, integration of rate equations, opposing reactions, parallel reactions,

and consecutive reactions, methods of analysis, measurement of rates, replacement of time with area variable, the Laplace transform, secular equation and eigen values, the steady state approximation.

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

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

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

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

TEXTBOOKS/REFRENCES

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/REFRENCES

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/REFRENCES

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. D. Atwood, *Inorganic and Organometallic Reaction Mechanism*, 2^{nd} Ed., Wiley-VCH (1997).
5. M. Bochmann, *Orgaonometallics and Complexes with Transition Metal-Carbon Sigma Bonds*, Oxford Science publications (2005).
6. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models if Inorganic Chemistry*, 3^{rd} Ed., Wiley (1994).
7. W. Kaim and B. Schwederski, *Bioinorganic chemistry: Inorganic Elements in the Chemistry of Life*, Wiley (2006).

CHY 421 Electrochemistry [3003]

Introduction and overview of electrode processes, potentials and thermodynamics of cells, kinetics of electrode reactions, mass transfer by migration and diffusion, basic potential step methods, potential sweep methods, polarography and pulse voltammetry, controlled-current techniques, methods involving forced convection-hydrodynamic methods, techniques based on concepts of impedance, bulk electrolysis methods, electrode reactions with coupled homogeneous chemical reactions, double-layer structure and adsorption, electroactive layers and modified electrodes, electrochemical instrumentation, scanning probe techniques, spectroelectrochemistry and other coupled characterization methods, photoelectrochemistry and electrogenerated chemiluminescence.

TEXTBOOKS/REFRENCES

1. A. J. Bard and L. R. Faulkner, *Electrochemical Methods Fundamentals and Applications*, 2^{nd} Ed.

Supplementary Reading:

1. R. Holze, *Experimental Electrochemistry: A Laboratory Textbook*.
2. Sawyer, Sobkowiak, and Roberts, *Electrochemistry for Chemists*, 2^{nd} Ed.
3. S. Glasstone, *An Introduction To Electrochemistry*.

CHY 422 Physical Organic Chemistry [3003]

Molecular Structure and Thermodynamics: Introduction to Structure and Models of Bonding, Strain and Stability, Solutions and Non-Covalent Binding Forces, Molecular Recognition and Supramolecular Chemistry, Acid Base Chemistry, Stereochemistry; Reactivity, Kinetics, and Mechanisms: Energy Surfaces and Kinetic Analyses, Experiments Related to Thermodynamics and Kinetics, Catalysis, Organic Reaction Mechanisms, Hammett Plot-LFET, QSAR, Organotransition Metal Reaction Mechanisms and Catalysis, Organic Polymer and Materials Chemistry; Electronic Structure, Theory and Applications: Advanced Concepts in Electronic Structure Theory, Electronic Organic Materials.

TEXTBOOKS/REFRENCES

1. Anslyn and Dougherty, *Modern Physical Organic Chemistry*.

Supplementary Reading:

1. Carey and Sundberg's, *Advanced Organic Chemistry, part A*, 5^{th} Ed.
2. E. L. Eliel, *Stereochemistry of carbon compounds*.
3. J. March, *Advanced Organic Chemistry*, 4^{th} Ed. or 5^{th} Ed.
4. Carpenter, *Determination of Organic Reaction Mechanisms*.
5. N. Isaacs, *Physical Organic Chemistry*.
6. Lowry and Richardson, *Mechanism and Theory in Organic Chemistry*, 3^{rd} Ed.
7. F. A. Caroll, *Structure and Mechanism in Organic Chemistry*.
8. B. Miller, *Advanced Organic Chemistry: Reactions and Mechanisms* (chapters 1 & 5).

CHY 423 Advanced Organic Chemistry III [3003]

Heteroatoms in organic synthesis: Sulfur: Sulfur stabilized anions, sulfonium salts, sulfonium ylides, sulfur stabilized cations, thiocarbonyl compounds, sulfoxides, oxidations with sulfur and selenium. Boron: organoboron reagents and reactions; Silicon: Organosilicon compounds an dtheir reactions, organotin compounds and their applications. Important catalyzed reactions such as Palladium catalyzed reactions including Heck, Stille, Sonogashira, Kumada, Suzuki & Negishi, Alkene metathesis, enyne metathesis, reductions, oxidations.

Retrosynthetic analysis: Synthesis backwards, disconnections, synthons, choosing disconnections, functional group interconversion, two group disconnections, C-C disconnections, donor-acceptor synthons, natural reactivity and umpolung; Synthesis of drugs: Benzocaine, saccharin, salbutamol, thyroxine, Muscalure, Grandisol, dofetilide; Complex Natural product Synthesis: Illustrative synthesis of complex natural products including cholesterol, squalene, heame, chlorophill, reserpine, Juvabione, Longifolene, Aphidicolin.

References:

TEXTBOOKS/REFRENCES

1. F. A. Carey and R. J. Sundberg, *Advanced organic chemistry*.
2. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic chemistry*.

List of Electives in Chemistry

1. Computational Chemistry

Computational Chemistry [3003]

Molecular Coordinates and Symmetry: Cartesian coordinates, Z-matrix, dihedral angle, determination of point group of a molecule, interface with software for visualization of structure in various formats, volume of molecules; Vibrations of Molecules: Harmonic approximation, reduced mass, vibrational frequencies, Hessian matrices, relationship with location of the transition states, local minima as well as isotope effects, quantum aspects of molecular vibrations, zero point energy corrections, normal modes, thermochemistry, simulation of IR spectra for simple molecules including H-bonded complexes.

Molecular Mechanics: Potential energy functions, parameterization strategies for non-bonding interactions, AMBER and CHARMM force fields. Applications; Geometry Optimization: The steepest descent method, Newton-Raphson methods, global versus local minima, Hessian based optimizations, problems on optimization of simple molecules and importance of normal modes.

Semiempirical implementations of MOT: Analogy with the Hckel theory, calculating bond order, charge order and charge density, values for and , problems on aromaticity, extended Hckel theory, CNDO, INDO, MINDO, AM1, PM3 formalism, ongoing development in semiemperical methods, Connections to tight binding methods in solids, U-J methods in solid state calculations.

Ab-initio Implementations of the Hartree-Fock MOT: Philosophy of Pople's model chemistry, Basis sets: Gaussian verus slater type orbitals, polarization functions and diffuse functions, Single-ψ , Multiple-ψ and split valence basis, Effective Core Potentials (ECP), SCF convergence, caution for open shell systems: RHF, UHF and ROHF calculations, examples.

Implementation of Electron Correlation in MOT: Multiconfiguration SCF theory, concept of active space, configuration interactions, full CI limit, perturbation theory: single reference and multi-reference, Coupled Cluster theory, single and double excitations (CCSD), size extensivity, importance of electron correlation for excited states.

Density Functional Theory: Rigorous foundation: HK and KS theorems, exchange-correlation functionals, analogy to Hartee-Fock solutions, LDA and GGA methods, hybrid functionals; Introduction to Molecular Dynam-

ics: Ensembles, external heat baths, thermostats, Nos-Hoover thermostat, averages, simulated annealing, examples.

TEXTBOOKS/REFRENCES

1. T. Heine, J. O. Joswig and A. Gelessus, *Computation Chemistry Workbook*, Wiley-VCH, 2009.
2. C. J. Cramer, *Essentials of Computation Chemistry*, 2nd Ed., Wiley-VCH, 2006.
3. F. Jensen, *Introduction to Computational Chemistry*, Wiley, 1998.
4. A. Szabo and N. S. Ostlund, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover,1996.
5. W. Koch and M. C. Holthhausen, *A Chemist's guide to Density Functional Theory*, 2nd Ed., Wiley-VCH, 2001.
6. J. B. Foresman and A. Frisch, *Exploring Chemistry with Electronic Structure Methods*, Gaussian Inc.
7. R. M. Martin, *Electronic Structure: Basic Theory and Practical Methods*, Cambridge University Press.
8. R. Hoffmann,*Solids and Surfaces: A Chemist's View of Bonding in Extended Structures*, Wiley-VCH.

LABORATORY COURSES

CHY 112 Chemistry Lab I [0031]

1. Qualitative inorganic salt analysis containing two anions and two cations (5 mixtures)
2. Inorganic preparations

   (a) Preparation of potash alum from scrap aluminium
   (b) Preparation of hexamineNi(II)chloride
   (c) Preparation of tetramineCu(II)sulphate

3. Organic preparations

   (a) Preparation of paracetamol
   (b) Preparation of aspirin

4. Introduction to Chromatography

   (a) Separation of metallic ions using paper chromatography
   (b) Separation of plant extracts using thin layer chromatography

5. Introduction to colorimetry using photoelectric colorimeter

(a) Estimation of iron
(b) Estimation of chromium
(c) Estimation of nickel
(d) Estimation of phosphate in cola drinks

6. Introduction to titrimetric analysis (acidimetry and alkalimetry)

   (a) Estimation of antacid capacity of antacid

CHY 122 Chemistry Lab II [0031]

1. Permanganometry

   (a) Estimation of hydrogen peroxide, nitrite and checking the purity of potassium nitrate
   (b) Estimation of Calcium

2. Dichrometry

   (a) Estimation of ferrous and ferric iron using N-Phenyl anthranilic acid indicator
   (b) Estimation of Zinc using potassium ferrocyanide

3. Iodometry

   (a) Estimation of barium
   (b) Estimation of copper
   (c) Estimation of dissolved oxygen
   (d) Estimation of available chlorine in bleaching powder

4. Iodimetry

   (a) Estimation of ascorbic acid in fruit juice

5. Argentometry

   (a) Estimation of chloride ion using Morh's and Volhard's methods
   (b) Estmation of potassium bromide using adsorption indicator

6. Complexometry

   (a) Estimation of calcium in milk powder (Eriochrome black T indicator)
   (b) Estimation of hardness of water (Eriochrome black T indicator)

(c) Estimation of calcium and magnesium using Patton and Reeders indicator
(d) Estimation of copper using fast sulphon black indicator
(e) Estimation of zinc and magnesium using (Eriochrome black T indicator)
(f) Estimation of nickel using Eriochrome black T indicator and murexide indicator

7. Gravimetric Analysis

(a) Estimation of barium/sulphate as barium sulphate
(b) Estimation of iron as ferric oxide

CHY 212 Chemistry Lab III [0031]

1. Determination of melting and boiling points
2. Purification of organic compounds by crystallization
3. Identification of organic functional groups (5 compounds)
4. Single stage preparations including nitration, acetylation, benzoylation, bromination, oxidation etc.
5. Two stage preparations

(a) conversion of acetanilide to p-bromoaniline
(b) conversion of acetanilide to p-nitroaniline
(c) conversion of nitrobenzene to m-nitroaniline

6. Organic estimations

(a) Estimation of phenol/ aniline
(b) Estimation of glucose
(c) Estimation of ester
(d) Saponification value of oil
(e) Iodine value of oil

CHY 222 Chemistry Lab IV [0031]

1. Phenol water system:

- Determine the mutual solubility curve of phenol and water and hence the consolute point.

- Determine the critical solution temperature of phenol and water in presence of (i) 1% of sodium chloride (ii) 0.5% of naphthalene and (iii) 1% succinic acid.
- Determination concentration of aqueous solution of KCl by studying mutual solubility of phenol and water.

2. Distribution Ratio:

   - Determine the distribution coefficient of iodine between an organic solvent such as carbon tetrachloride, carbon disulphide, kerosene etc. and water at a given temperature
   - Determine the equilibrium constant of the reaction $KI + I_2 \rightleftharpoons KI_3$ by distribution method
   - Study the distribution of benzoic acid /succinic acid between toluene and water
   - Determine the formula of the complex ion formed between the cupric ion and ammonia by distribution method

3. Solid liquid equilibrium:

   - Determination of molal depression constant of naphthalene
   - Determination of molecular weight of solute

4. Transition temperature:

   - Determination of transition temperature of a salt hydrate
   - Determination of transition temperature coefficient of a salt hydrate
   - Determination of molecular weight

5. Three component system

   (a) Construction of the triangular phase diagram of acetic acid, chloroform and water
   (b) Construction of the tie line
   (c) Determination of the composition of the given mixture

6. Chemical kinetics

   - Clock Reaction: Study of clock reaction and determination of the factors affecting a reaction
   - Determination of the rate constant of hydrolysis of methyl acetate catalyzed 0.5M hydrochloric acid

- Determination of the rate constant of the hydrolysis of ester by sodium hydroxide reaction

7. Conductometric titration
   - Conductometric titration of
   - Strong acid >< Strong base
   - Strong acid >< Weak base
   - Weak acid >< Strong base
   - Precipitation titration
8. Estimation using conductometric titrations
   - Mixture of hydrochloric acid and acetic acid
   - Mixture of hydrochloric acid and oxalic acid
   - Mixture of acetic acid and oxalic acid
   - Mixture of sulphuric acid, acetic acid and copper sulphate
9. Potentiometric titration
   - HCl >< NaOH using quinhydrode as the indicator electrode
   - Orthophosphoric acid >< NaOH using quinhydrode as the indicator electrode
   - Mixture of KCl, KBr and KI using silver electrode
   - Ferrous ammonium sulphate >< Potassium dichromate using Pt electrode

CHY 315 Advanced Organic Chemistry Laboratory [0093]

1. Separation and quantification of ternary mixtures. Determination of purity by melting points and TLC. Mixtures No. 1-4
2. SN1 and SN2 reactions
3. (a) Determination of moisture content in the organic solvents using Karl-Fischer titration
   (b) Drying of organic solvents
4. Estimation of nitrogen in the given organic compound by Kjeldahl's method
5. Extraction of eugenol from cloves by steam distillation
6. Cycloaddition reaction: (Diels- Alder reaction) Diels-Alder reaction of furan and N-phenylmaleimide, preference for endo or exo-product formation

7. (a) Claisen-Schimidt reaction- Preparation of benzal acetophenone
   (b) Malonic ester synthesis- cyclobutane carboxylic acid
8. Multistage preparations and spectroscopic characterization
   (a) Conversion of bromobenzene to triphenyl carbinol and then to tritylchloride
   (b) Preparation of vanilline and its derivatives fron p-hydroxybezaldehyde
   (c) Benzaldehyde to methylstyrene and to 1-phenyl 1,2-dihydroxypropane
   (d) Preparation of benzotriazole from o-nitroaniline
   (e) Preparation of sys-tribromobenzene from aniline
   (f) Validity of Huckel's 4n+2 rule: Synthesis of triphenyl methyl fluoroborate and tropyllium iodide
   (a) Chemiluminesence: Synthesis of cyalume and chemiluminescence
9. Molecular rearrangement
   (a) Green photochemical reaction (Photoreduction of benzophenone to benzopinacol and then to benzopinacolone)
   (b) Rearrangement of diazoaminobenzene to p-aminoazobenzene
   (c) Benzil Benzilic acid rearrangement
   (d) Preparation of caprolactum from cyclohexanone and nylon-6
10. Ionic liquids
    - Preparation of tetrabutylammonium tribromide (TBATB) and Bromination of Chalcone
    - Preparation of 1-pentyl-3-methylimidazolium bromide (pmIm) and Preparation of 2-phenylbenzothiazoles catalyzed by ionic liquid.
11. Phase transfer catalyst
    - Wittig reaction: The preparation and purification of trans-stilbenes
12. Microwave oven assisted organic syntheses
13. Multi-step synthesis coenzyme catalyzed synthesis of Benzoin and derivatives
    - Part 1: Synthesis of Benzoin
    - Part 2: Synthesis of Benzil
    - Part 3: Synthesis of Benzilic Acid
    - Part 4: Synthesis of Benzoic acid from Benzaldehyde

CHY 325 Advanced Inorganic Chemistry Laboratory [0093]

1. Simple Gravemetric analysis of Ni, Cu, etc.
2. Synthesis of a solid acid, 12-Tungstosilicic acid, H_4 Si $W_{12}O_{40}.7H_2O$
   - Synthesis of Zeolite ZSM-5
3. The preparation of Potassium tris(oxalato) ferrate(III) trihydrate $K_3[Fe(C_2O_4)_3]$ and its characterization
4. The Mechanism of Aquation of trans - dichlorobis (1, 2 - diaminoethane) cobalt(III) chloride
5. Preparation of Ferrocene and its reactions
6. Sequential synthesis of several complexes containing Mo – Mo quadrupole bond
7. Synthesis and reactions of Potassium tetrathionate
8. Synthesis and magnetic properties of tetragonal Ni(II) complexes
9. Synthesis of Co(III) complexes and characterization
10. Microwave assisted synthesis of 5,10,15,20 - tetraphenylporphyrin
11. Synthesis and characterization of an oxygen-carrying Cobalt complex which mimics Haemoglobin
12. Binding of a small molecule to a Metalloprotein: Determination of the Equilibrium Binding Constant
13. Reduction potential of cytochrome C
14. Ammonia-Borane related N-B-H compounds and materials
15. Olefin epoxidation with Mn (salen complex)
16. Synthesis and kinetics study of Wilkinson's catalyst
17. Studies on ligand field strength: Chromium complexes with ligands of different ?0
18. Common geometries of pentacoordinate complexes: preparation of acetylacetonate complexes

CHY 415 Advanced Physical Chemistry Laboratory [0093]

1. Determination of molecular weights by cryoscopic method
   (a) using water
   (b) benzene
   (c) Camphor as the solvents
2. Viscosity measurements

(a) Determination of coefficient of viscosity using Ostwald's viscometer
(b) Variation of viscosity of a liquid with temperature
(c) Verification of J. Kendall's equation and determination of the composition of a mixture of two liquids
(d) Determination of radius of glycerol molecule
(e) Determination of molecular weight of polymers

3. Surface tension

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

4. Thermochemistry

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

5. Refractometry

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

6. Spectophotometry

(a) Test the validity of Beer-Lambert's law
(b) Determination of composition of binary mixture of $KMnO_4$ and $K_2Cr_2O_7$
(c) Determination of dissociation constant of weak acid/ weak base

(d) Study the complex formation between Fe(III) and salicylic acid, and find the formula and stability constant of the complex
(e) Investigate the complex formation of (a) Fe(III) and thiocyanate (b) Ni(II) and ethylenediamine by Job's method

7. Dipole measurement

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

8. Equilibrium and dissociation constant

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

9. Chemical Kinetics

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

10. Electrolytic conductance

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

11. Transport number

    - Determination of transport number by moving boundary and Hitroff methods

12. Electromotive force

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

13. Surface Chemistry

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

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

Mathematics Syllabus

MAT 111 Introduction to Algebra [3103]

Linear Algebra: Fields, systems of linear equations, matrices and elementary row operations, row reduced echelon matrices, matrix multiplication, invertible matrices, rank of a matrix. Definition of a linear vector space and examples; linear independence of vectors, basis and dimension, subspaces; linear transformations, isomorphism, linear functionals, the double dual; inner product, orthogonal basis, Gram-Schmidt orthogonalization process; linear operators; orthogonal and Hermitian matrices, eigenvectors of a matrix and matrix diagonalization, applications.

Group Theory: Definition and examples of groups, finite groups, abelian and cyclic groups, subgroups, functions and permutations, groups of permutations, cycles and cyclic notation, even and odd permutations, the alternating group. Isomorphism, Cayley's theorem, cosets, inner automorphism, normal subgroups and quotient groups, applications.

TEXTBOOKS/REFERENCES

1. Michael Artin, *Algebra*, 2nd Edition, Addison Wesley, 2010.
2. K. Hoffman and R. Kunze, *Linear Algebra*, 2^{nd} edition, Pearson Education, New Delhi, 2006.
3. G. Strang, *Linear Algebra and its Applications*, 4th Edition, Brooks/Cole India 2006.
4. I. N. Herstein, *Topics in Algebra*, 2^{nd} Edition, Wiley and Sons, 1996.
5. S. Lang, *Undergraduate Algebra*, 3rd Edn., Springer, 2004.
6. P. Halmos, *Finite-Dimensional Vector Spaces*, Van Nostrand, Princeton, N.J, 1958.

MAT 121 Introductory Analysis I [3103]

The Natural Numbers: The Peano axioms, addition, multiplication. Set Theory: Fundamentals, functions, images and inverse images, Cartesian product, cardinality of sets. Integers and Rationals: The integers, The rationals, absolute value and exponentiation, gaps in the rational numbers.

The real numbers: Cauchy sequence, construction of the real numbers, ordering of reals, the least upper bound property.

Limits of Sequences: Convergence and limit laws, suprema and infima of sequences, limsup, liminf, and limit points, some standard limits, Subsequences.

Series: Finite and infinite series, sums of non-negative numbers, absolute and conditional convergence of an infinite series, tests of convergence, examples. Power Series: Convergence of power series, radius of convergence, properties of power series.

Continuous functions on **R**: Formal definition, continuity and discontinuity of a function at a point; left and right continuity, examples of continuous and discontinuous functions, the Maximum principle, intermediate value theorem, monotonic functions, uniform continuity, limits at infinity.

Differentiation of functions: Definition and basic properties, local maxima, local minima, and derivatives, monotone functions and derivatives, inverse functions and derivatives, Rolle's theorem, mean value theorem, Taylor's theorem.

Riemann Integration: Partitions, piecewise constant functions, upper and lower Riemann integrals, basic properties of the Riemann integral, Riemann integrability of continuous functions, monotone functions, and discontinuous functions, non-Riemann integrable functions, the fundamental theorems of calculus, the consequences of the fundamental theorems.

TEXTBOOKS/REFERENCES

1. Tom M. Apostol, *Calculus*, Vol. 1, 2^{nd} edition, Wiley, 2007
2. Robert G. Bartle, Donald R. Sherbert, *Introduction to Real Analysis*, 4^{th} edition, Wiley, 2011
3. Richard R. Goldberg, *Methods of Real Analysis*, 2^{rd} edition, Wiley, 1976
4. W. Rudin, *Principles of Mathematical Analysis*, 3^{rd} edition, McGraw-Hill India, 1953
5. S. Lang, *A First Course in Calculus*, 5^{th} edition, Springer (India), New Delhi, 2006
6. Terence Tao, *Analysis I*, Hindustan Book Agency, 2006

7. G. B. Thomas and R. L. Finney, *Calculus and Analytic Geometry*, 9^{th} edition, Pearson Education, New Delhi, 2005
8. James Stewart, *Calculus: Concepts and Contexts*, 3^{rd} edition, Thomson Brooks/Cole, 2005
9. E. Kreyszig, *Advanced Engineering Mathematics*, 8^{th} edition, Wiley & Sons, 2006

MAT 211 Introductory Analysis II [3103]

Limits and continuity of functions of several variables: Definition, properties and examples. Differentiability: Partial derivatives, total differential, composite functions, chain rule, partial derivatives of higher order, change of variables, calculation of second order partial derivatives, Jacobians, directional derivatives, gradient and curl. Inverse and implicit function theorems (without proof), applications. Unconstrained maxima and minima, constrained optimization, Lagrange multipliers.

Improper Integrals: Improper integrals of first and second kind, tests for convergence of improper integrals of various kinds, tests for convergence of integral of the product, Beta and Gamma functions.

Integral as a function of a parameter: Definite integral as a function of a parameter, uniform convergence of improper integrals, consequences of uniform convergence of improper integrals.

Multiple Integrals: Double integrals on rectangular regions, conditions of integrability, properties of integrable functions, repeated or iterated integrals, double integrals over any finite region, change in the order of integration, triple integrals over any bounded domain, evaluation of multiple integral by change of variables. Surface area, volume of a region. Theorems of Green, Gauss, and Stokes (without proof), applications.

TEXTBOOKS/REFERENCES

1. Tom M. Apostol, *Calculus*, Vol. 2, 2^{nd} edition, Wiley (India), 2007.
2. C.C. Pugh, *Real Mathematical Analysis*, Springer, 2002.
3. J. Munkres, *Analysis on Manifolds*, Westview Press, 1977.
4. S. Lang, *Calculus of Several Variables*, 3^{rd} edition, Springer, 1987.
5. Terence Tao, *Analysis II*, Hindustan Book Agency, 2006.
6. W. Rudin, *Principles of Mathematical Analysis*, 3^{rd} edition, McGraw-Hill India, 1976.

7. G. B. Thomas and R. L. Finney, *Calculus and Analytic Geometry*, 9^{th} edition, Pearson Education, New Delhi, 2005
8. James Stewart, *Calculus: Concepts and Contexts*, 3^{rd} edition, Thomson Brooks/Cole, 2005.
9. A. E. Taylor and W. R. Mann, *Advanced Calculus*, 3^{rd} Edition, Wiley & Sons, 1983.
10. University of California Berkley Video Lectures: http://academicearth.org/courses/multivariable-calculus

MAT 221 Introduction to Statistics [3103]

Basic probability: Set operations, counting, finite sample spaces, axioms of mathematical probability, conditional probability, independence of events, Bayes' Rule, Bernoulli trials, Poisson trials, multinomial law, infinite sequence of Bernoulli trials, Markov chains.

Random variables and probability distributions: Univariate, bivariate and multivariate random variables, cumulative and marginal distribution functions, conditional and multivariate distributions, transformation of random variables in one and two dimensions.

Mathematical expectations: Expectations for univariate and bivariate distributions, moments, variance, standard deviation, higher order moments, covariance, correlation, moment generating functions, characteristic functions, conditional expectation.

Discrete and continuous distributions and limit theorems: Binomial distribution, geometric distribution, Poisson distribution, normal distribution, exponential distribution, Gamma distribution, Beta distribution, central limit theorem, Tchebycheff's inequality, law of large numbers.

Estimation of parameters: Bias of estimates, confidence intervals, minimum variance unbiased estimation, Bayes' estimators, moment estimators, maximum likelihood estimators, chi-square distribution, confidence intervals for parameters of normal distribution.

Hypothesis testing: Tests for means and variances, hypothesis testing and confidence intervals, Bayes' decision rules, power of tests, goodness-of-fit tests, Kolmogorov-Smirnov goodness-of-fit test.

TEXTBOOKS/REFERENCES

1. William Feller, *Introduction to Probability Theory and its Applications*, Vol. 1, 3rd Edition, Wiley, 1968.
2. Sheldon Ross, *A first course in Probability*, 8th Edition, Prentice Hall, 2009.
3. Sheldon Ross, *Introductory Statistics*, 2nd Edition, Elsevier (India), 2006.
4. Sheldon Ross, *Introduction to Probability and Statistics for Engineers And Scientists*, 3rd Edition, Elsevier (India), 2004.
5. C.M. Grinstead and J.L. Snell, *Introduction to Probability*, 2nd Edition, American Mathematical Society, 1997.
6. D.C. Montgomery and G.C. Runger, *Applied Statistics and Probability for Engineers*, Wiley, 1994.
7. Walter Rosenkrantz, *Introduction to Probability and Statistics for Science, Engineering and Finance*, Chapman & Hall/CRC, 2008.
8. Amritava Gupta, *Groundwork of Mathematical Probability and Statistics*, 5th Edition, Academic Publishers, 2008.

MAT 311 Real Analysis [3003]

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 312 Discrete Mathematics [3003]

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 313 Abstract Algebra [3003]

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 314 Advanced Linear Algebra [3003]

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

adjoint operators.

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

TEXTBOOKS/REFERENCES

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

MAT 315 Numerical Analysis [3003]

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 321 Complex Analysis [3003]

PREREQUISITE

1. MAT 311-Real Analysis

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 322 Measure Theory and Integration [3003]

PREREQUISITE

1. MAT 311-Real Analysis

Lebesgue measure: 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 313-Abstract Algebra

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 324 Multivariate Analysis [3003]

PREREQUISITES

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 325 General Topology [3003]

PREREQUISITE

1. MAT 311-Real Analysis

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 411 Functional Analysis [3003]

PREREQUISITES

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

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 412 Probability Theory and Random Processes [3003]

PREREQUISITE

1. MAT 322-Measure Theory and Integration

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 413 Number Theory and Cryptography [3003]

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

Arithmetic functions, Euler's totient function, perfect numbers, Mobius inversion formula. Linear diophantine equations, Pythagorean triples, Fermat's Last Theorem, Lagrange's theorem, Waring's problem, Hardy-Littlewood circle method. Irrationality of e and 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.

MAT 421 Advanced Analysis [3003]

PREREQUISITE

1. MAT 411-Functional Analysis

Distributions: test functions and distributions, operations with distributions, support and singular support of distributions, convolution of functions, convolutions of distributions, fundamental solutions, The Fourier transform, Plancherel's theorem, the Schwartz space, the Fourier inversion formula, tempered distributions.

Sobolev spaces: weak derivatives, definition and basic properties of Sobolev spaces, approximation by smooth functions, extension theorems, imbedding theorems, compactness theorems, Poincaré inequality, dual spaces, fractional order spaces, trace theory.

Non-linear Analysis: Fixed point theorems with Applications- Banach contraction mapping theorem, Brouwer fixed point theorem, Leray-Schouder fixed point theorem.

TEXTBOOKS/REFERENCES

1. E.H. Lieb and M. Loss, Analysis, 2nd Edition, American Mathematical Society, 2001.
2. L.C. Evans, *Partial Differential Equations*, 2nd Edition, American Mathematical Society, 2010.
3. S. Kesavan, *Topics in Functional Analysis and Applications*, Wiley, 1989.
4. L. Hörmander, *The Analysis of Linear Partial Differential Operators I: Distribution Theory and Fourier Analysis*, 2nd Edition, Springer-Verlag, 1990.
5. E. Zeidler, *Nonlinear Functional Analysis and its Applications, Vol I*, Springer-Verlag, Berlin, 1985.
6. M.C. Joshi and R.K. Bose, *Some Topics in Nonlinear Functional Analysis*, Wiley Eastern, New Delhi, 1985.

7. E.M. Stein and R. Shakarchi, *Fourier Analysis*, Princeton University Press, 2003.
8. G. B. Folland, *Real Analysis: Modern Techniques and Their Applications*, 2nd Edition, John Wiley & Sons, 1999.
9. R.A. Adams and J.F. Fournier, *Sobolev Spaces*, 2nd Edition, Academic Press, 2003.
10. J. Barros-Neto, *An Introduction to the Theory of Distributions*, Krieger, 1981.

MAT 422 Partial Differential Equations [3003]

PREREQUISITES

1. MAT 312-Theory of Ordinary Differential Equations
2. MAT 411-Functional Analysis

Three important linear PDEs: Laplace's equation and the heat equation - fundamental solution, mean-value formula, maximum principle, uniqueness and regularity, local estimates for solutions. Wave equation - solution by spherical means, non-homogeneous problem. Solutions by transform methods.

Second-order linear elliptic equations: weak formulation, Lax-Milgram theorem, energy estimates, existence theorems, boundary regularity, maximum principles, Harnack's inequality.

Second-order linear parabolic equations: energy methods, existence of weak solutions, regularity.

TEXTBOOKS/REFERENCES

1. Lawrence C. Evans, *Partial Differential Equations*, 2nd Edition, American Mathematical Society, 2010.
2. Gerald B. Folland, *Introduction to Partial Differential Equations*, 2nd Edition, Princeton University Press, 1995
3. Fritz John, *Partial Differential Equations*, 4th Edition, Springer, 1981.
4. Michael E. Taylor, *Partial Differential Equations I*, 2nd Edition, Springer, 2010.
5. S. Kesavan, *Topics in Functional Analysis and Applications*, Wiley, 1989.

MAT 423 Combinatorics and Graph Theory [3003]

PREREQUISITE

1. MAT 313-Discrete Mathematics

Binomial coefficient identities, Sperner's theorem, multinomial theorem, chains and antichains, Dilworth's theorem, Erdős-Szekeres theorem. Principle of inclusion and exclusion, combinations with repetition, derangements, permutations with forbidden positions. Recurrence relations, generating functions, Catalan numbers, Stirling numbers, partitions. Block designs, Steiner triple systems, Latin squares, finite projective planes, error-correcting codes.

Review of graphs and digraphs, tournaments, distances in graphs and trees, spanning trees in graphs, Cayley's formula, Matrix-tree theorem. Matchings and covers, Hall's theorem, Tutte's 1-factor theorem, cuts and connectivity, Menger's theorem, network flows, Ford-Fulkerson theorem. Planar graphs, Euler's formula, five colour theorem, Kuratowski's theorem. Vertex colouring, Brooks' theorem, Turán's theorem, edge-colouring, Vizing's theorem, Ramsey's theorem, probabilistic method.

TEXTBOOKS/REFERENCES

1. Richard A. Brualdi, *Introductory Combinatorics*, 5th Edition, Pearson, 2010.
2. Douglas B. West, *Introduction to Graph Theory*, 2nd Edition, Prentice Hall, 2001.
3. J. H. van Lint and R. M. Wilson, *A Course in Combinatorics*, 2nd Edition, Cambridge University Press, 2001.
4. S. M. Cioaba and M. Ram Murty, *A First Course in Graph Theory and Combinatorics*, Hindustan Book Agency, 2009.

MAT 424 Differential Geometry [3003]

PREREQUISITE

1. MAT 324-Multivariate Analysis

Manifolds: Manifolds definition, examples, manifolds with boundary, smooth functions, maps between manifolds, Lie groups.

Tangents spaces: tangent vectors, tangent bundle, Lie brackets, Lie algebra of Lie group, covectors and cotangent bundle.

Submersion and Immersion: Submersion, Immersion and embeddings.

Differential forms: Multi-linear algebra, tensors, alternating tensors, wedge product, differential forms on manifolds, orientable manifolds, generalized Stoke's theorem and its applications.

TEXTBOOKS/REFERENCES

1. John M. Lee, *Introduction to Smooth Manifolds*, Springer, 2002.
2. Jeffrey M. Lee, *Manifolds and Differential Geometry*, American Mathematical Society, 2009.
3. J.R. Munkres, *Analysis on Manifolds*, Westview Press, 1997.
4. S. Kumaresan, *A Course in Differential Geometry and Lie Groups*, Hindustan Book Agency, 2002.
5. W. Klingenberg, *A Course in Differential Geometry*, Springer-Verlag, 1978.
6. Christian Bar, *Elementary Differential Geometry*, Cambridge University Press, 2010.
7. R.S. Millman and G.D. Parker, *Elements of Differential Geometry*, Prentice Hall Inc., 1977.

Partial List of Electives

1. ALGEBRAIC GEOMETRY
2. ALGEBRAIC NUMBER THEORY
3. ALGEBRAIC TOPOLOGY
4. RINGS AND MODULES
5. LIE GROUPS AND LIE ALGEBRAS
6. REPRESENTATION THEORY
7. NONNEGATIVE MATRICES AND APPLICATIONS
8. ADVANCED COMBINATORICS
9. DIOPHANTINE APPROXIMATIONS
10. HARMONIC ANALYSIS
11. OPERATOR THEORY
12. ADVANCED PARTIAL DIFFERENTIAL EQUATIONS
13. STOCHASTIC ANALYSIS
14. CONTROL THEORY
15. MATHEMATICAL FINANCE
16. MATHEMATICAL FLUID DYNAMICS
17. CALCULUS OF VARIATIONS
18. OPERATIONS RESEARCH
19. PROGRAMMING AND DATA STRUCTURES
20. FINITE ELEMENT METHODS

Physics Syllabus

THEORY COURSES

PHY 111 Mechanics [3103]

Introduction to essential mathematical tools; Newtons laws-a recapitulation:- Structure and validity of the laws, The concept of inertial reference frames and Galilean relativity, Non-inertial frames and pseudo-forces; Systems in one dimension: Conceptual issues, Illustrations of various methods of solving the EOMs, Work energy theorem and energy conservation in ID motion, The use of potential energy graphs to understand motion, The small amplitude approximation and oscillations:- The simple harmonic oscillator; the damped oscillator; the forced harmonic oscillator; nonlinear oscillators.

Motion in three dimensions: Equations of motion in Cartesian and Polar Coordinates; The work energy theorem in 3D; conservative and non-conservative forces; force as the gradient of potential energy; Conservation of angular momentum for a point particle; Applications: The projectile; charged particle in a uniform electromagnetic field; Central force field motion; equations for the orbit, The Kepler problem, The effective potential and the stability of circular orbits.

Systems of particles: Conservation laws for linear momentum, angular momentum and energy. Center of mass; The concept of equivalent forces; Collisions; Two-body systems and the concept of reduced mass; Rigid bodies: The angular velocity vector; Rotating reference frames and pseudo-forces; The moment of inertia tensor: Connection between angular momentum and angular velocity; calculation of moment of inertia for simple bodies; principal axes.

TEXTBOOKS/REFERENCES

1. C. Knight, W. D. Ruderman, M. A. Helmholz, C. A. Moyer and B. J. Kittel, *Berkeley Physics Course: Vol. I – Mechanics*, McGraw-Hill, 1965.

2. D. Kleppner and R. Kolenkow, *An introduction to Mechanics*, McGraw-Hill Science/ Engineering/ Math ,1973.
3. Serway and Jewett, *Physics for Scientists and Engineers*, Brooks/Cole Publishers 2004.

PHY 121 Electromagnetic Theory [3103]

Electrostatics: Coulomb's law and Gauss's law Simple application; Differential form of the Gauss's law; Electrostatic potential, electrostatic energy Calculation for some simple cases;Conductors; Surface charges induced on a conductor; Solutions of Poisson's and Laplace's equations. Method of images; Solution by the method of separation of variables in cartesian and spherical polar coordinates; Potential due to an arbitrary charge distribution; Monopole and dipole terms; Electrical field and potential due to a point dipole; Dipole in an electric field.

Magnetostatics: Biot - Savart and Ampere's laws; Ampere's law in differential form; Magnetic vector potential; Determination of magnetic fields for simple cases. Energy in a magnetic field; Current electricity: Electromotive force.Ohm's law; Motional emf; Electromagnetic induction;Faraday's law; Self inductance and mutual inductance; Impedance; LCR circuit.

Electrodynamics: Maxwell's equations; Equation of continuity; Poynting's theorem; Electric and magnetic fields in matter; Fields D and H; Constitutive relations; Linear and nonlinear media; Electromagnetic Waves: EM waves in vacuum and in a dielectric medium; Boundary conditions on an interface; Reflection and transmission at an interface; Conducting surface.

TEXTBOOKS/REFERENCES

1. D. J. Griffths, *Introduction to Electrodynamics*, Prentice-Hall India, 2007.
2. E. M. Purcell, *Berkeley Physics course: Vol 2. Electricity and Magnetism*, McGraw Hill.
3. Serway and Jewett, *Physics for Scientists and Engineers*, Brooks/Cole Publishers, 2004.

PHY 211 Optics

What is light? The corpuscular model and wave model, Particle nature of light and wave nature of matter, Uncertainty principle, Single slit diffraction experiment, Double Slit interference experiment; Geometrical Optics: Fermat's Principle, Laws of reflection and refraction from Fermat's principle, The ray equation and its solutions; Refraction at a Single Spherical Surface, Reflection by a single Spherical Surface, The thin lens, Thin lens equation, Matrix method in paraxial optics, Analytical Ray tracing, Thick and Thin lens combinations, Aberrations, Prisms, Optical Systems.

Wave Optics: Wave Motion, One dimentional waves, Harmonic Waves, Phase Velocity, Group Velocity of a wave packet, The superposition principle, Phasors and the addition of waves, The three-dimensional wave equation, Spherical waves, Cylindrical waves, Anharmonic periodic waves; Polarisation: The nature of polarized light, Polarizers, Malus law, Dichroism, Birefrigence, Scattering and Polarization, Polarization by reflection, Retarders; full-wave plate, half-wave plate, quarter-wave plate, Circular Polarizers, Polarization of Polychromatic light.

Interference: Superposition of waves, Condition for interference, Coherence, Two beam interference by division of wavefront; Fresnel' Biprism, Interference by division of amplitude; interference by a plane parallel film, Newton's rings, Michelson interferometer, Multiple beam interferometry; Fabry-perot interferometer.

Diffraction: Fraunhofer diffraction; Single slit diffraction, Diffraction by a circular aperture, Two-slit fraunhofer diffraction, N-slit Fraunhofer diffraction, The diffraction grating, Oblique incidence, X-ray diffraction; Fraunhofer diffraction and Fourier optics: The Fresnel diffraction integral, The Franhofer approximation, Fraunhofer diffraction by a Rectangular and circular aperture, Array of identical apertures; Fresnel diffraction: Fresnel Half-period zones, The zone-plate, Diffraction by a straight edge.

TEXTBOOKS/REFERENCES

1. Ajoy Ghatak, *Optics*, Tata Mgraw-Hill, 2009.
2. Eugune Hecht and A. R. Ganesan, *Optics*, Addison Wesley Longman,2002.
3. Frank S. Crawford, *Waves: Berkeley Physics Course Vol. 3*, Tata Mgraw Hill, 2008.

PHY 221 Thermal and Statistical Physics [3103]

Macroscopic description of the state, Extensive and intensive variables, Thermodynamic variables (pressure, temperature, etc), Thermal equilibrium, Equation of State, Zeroth Law of Thermodynamics, Temperature Scales; Work, Heat and Internal energy, Thermodynamic Processes (reversible, irreversible, quasi-static, adiabatic, isothermal, etc), First law of thermodynamics, Specific heat capacity, Enthalpy.

The Second Law of thermodynamics, Carnot cycle and Kelvin temperature scale, Clausius' theorem, entropy and its physical interpretation, entropy change for simple processes, thermodynamic functions (Helmholtz free energy, Gibbs free energy, etc), conditions of equilibrium, Maxwell's relations; Equilibrium between two phases, general equilibrium conditions, the Clausius- Clapeyron equation, phase transformation of substances; The third law of thermodynamics.

Microscopic versus macroscopic points of view, kinetic theory of gases, Calculation of pressure, kinetic interpretation of temperature, mean free path, Maxwell's distribution, equipartition of energy; Concept of ensembles, Micro-canonical, Canonical, Grand-canonical ensembles, Partition function, Postulates of classical statistical mechanics, Derivation of thermodynamics, Equation of state for ideal and real gases, Gibbs paradox.

TEXTBOOKS/REFERENCES

1. F. Reif, *Statistical Physics: Berkeley Physics Course Vol. 5*, Tata Mcgraw-hill, 2011.
2. F. Mandl, *Statistical Physics*, John Wiley & Sons , 1991.
3. M. W. Zemanski and R. H. Dittman, *Heat and Thermodynamics*, McGraw-Hill, 1997.

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 equa-

tions: 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 I [3003]

Basic concepts of semiconductors, conduction and doping, PN junction, diode characteristics, forward bias, reverse bias, static and dynamic resistance, junction capacitance, Diode approximations, equivalent circuit, Zener and avalanche breakdown, Heterojunction; Thevenins and Nortons theorems, Voltage and current source; Diode circuits - Rectifiers half wave and full wave efficiency and ripple factor, Voltage multiplier, clipper and clamper circuits.

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

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

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

TEXTBOOKS/REFERENCES

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

PHY 314 Quantum Mechanics I [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. D. J. Griffiths, *Introduction to quantum mechanics*, Benjamin-Cummins, 2004.
2. J. J. Sakurai, *Modern quantum mechanics*, Addison-Wesley, 1994.
3. R. Shankar, *Principles of quantum mechanics*, Plenum Publishers, 1994.

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 I [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 II [3003]

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

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

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

TEXTBOOKS/REFERENCES

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

PHY 324 Electrodynamics and Special Theory of Relativity [3003]

Review of Maxwell's equations and basic electrodynamics.

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

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

Electromagnetic field equations: The action function of the 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 II [3003]

PREREQUISITE

1. PHY 322: Condensed Matter Physics I

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 II [3003]

PREREQUISITES

1. PHY 314: Quantum Mechanics I
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.

PHY 421 High Energy Physics [3003]

PREREQUISITE

1. PHY 413: Quantum Mechanics II

Introduction: Units energy, momentum and mass; Cross-Sections: Total and partial cross-sections, Differential cross-sections, Elastic scattering, Form factor $F(q)$, Born approximation, Fourier relationship between $\rho(r)$ and $F(q)$; Relativistic Kinematics: 4-vectors $P = (\mathbf{p}, iE)$, 4-momentum transfer, $\mathbf{q}$, Lorenz Invariant Phase space.

Classification of Particles:Fermions and bosons - constituents of matter and fields, Introduction to the Standard Model, Leptons and quarks; Interactions and Fields:Exchange bosons, The 4 fundamental forces their ranges and relative strengths, Feynman diagrams, Virtual particles, Yukawa potential.

Invariance Principles and Conservation Laws: Origin of conservation laws, properties of space-time, Conservation of p, E and L, Global phase or gauge transformations, Properties of the gauge groups $U(1)$, $SU(2)$ and $SU(3)$ (Additive and) multiplicative conservation laws, charge conjugation (C), parity (P) and time-reversal (T) symmetries, CPT theorem.

Fundamental Interactions:-Electromagnetic - QED, electron self-energy, vacuum polarisation, renormalisation. Magnetic moments, $g2$ experiment and theory; Weak -Low energies, beta decay, $W+$, W. High energy divergences and electroweak unification, Z_0. e^+ e^- annihilation experiments, number of fermion generations, partity violation; Strong - QCD, quarks and gluons, colour, αs (running), Allowed hadrons, hadronisation and jets.

Properties of Quarks: Isospin & strangeness, charm, beauty (bottom), top,

Quark content of hadrons, Strangeness regeneration.e^+ e^- scattering and annihilation, time-like and space-like virtual photons, R and colour factor, Deep inelastic scattering, scaling, Jets and gluon bremsstrahlung; Experimentation for Particle Physics, Principles of Particle Detectors, Interaction of particles with matter, gaseous detectors, scintillators and photon detectors, tracking of charged particles; principles of calorimetry; data acquisition and triggering; examples of existing detectors and detector performance.

TEXTBOOKS/REFERENCES

1. Donald H. Perkins, *Introduction to High Energy Physics*, Addison-Wesley.
2. F. Halzen and A. D. Martin, *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, Wiley.
3. D. J. Griffiths, *Introduction to Elementary Particles*, Wiley.
4. I. S. Hughes, *Elementary Particles*, Cambridge.

PHY 422 Atomic and Molecular Physics [3003]

PREREQUISITE

1. PHY 413: Quantum Mechanics II

One electron atoms: Hydrogenic atoms, transition rates, dipole approximation, Einstein coefficients, selection rules and spectrum, line shape and line widths, the photoelectric effect, Fine structure, Zeeman and Stark effects, Lamb shift, Hyperfine structure; Two electron atoms: Para and Ortho states, Energy level scheme, ground state, excited state, doubly excited states.

Many electron atoms: The central field approximation, Hartree-Forck method and self consistent field, L-S coupling, j-j coupling, Zeeman effect, quadratic Stark effect, X-ray spectra; Molecules: Born-Oppenheimer separation for diatomic molecules, rotation and vibration of diatomic molecules, electronic structure, rotational and vibrational energy levels, the nuclear spin.

Atomic collisions: Review of quantum mechanical scattering including partial waves and Born approximation, electron scattering, ionization, resonance phenomena, atom-atom collisions, long range interactions, elastic scattering of atoms at low velocities; Interaction of light and matter: The electric field of moving charges, Dipole radiation, Thompson scattering, Synchrotron radiation, Bremsstrahlung.

TEXTBOOKS/REFERENCES

1. B. H. Brandsen and C. J. Joachaim, *Physics of atoms and molecules*, Longman, 1983.
2. J. J. Sakurai, *Modern Quantum Mechanics*, Addison-Wesley.
3. Cohen-Tannoudji and Diu-Laloë, *Quantum Mechanics* (2 volumes), Wiley.
4. L. D. Landau and E. M. Lifshitz, *Classical Theory of Fields*, Vol-2 of course of theoretical physics, Pergamon, 2000.

PHY 423 Computational Techniques and Programming Languages [3003]

Numerical Approach: Need for computational physics, Computers in Physics? Working Program, Testing the code,Assessing the errors, Programming guidelines, Brief introduction to Matlab/Octave/Python/C.

Ordinary Differential Equations: Methods: Euler Method, Runga-Kutta Methods, Verlet Method; *Physical Problems:* Projectile Motion, Nuclear decay, Pendulum with dissipation, Forced pendulum, Chaotic pendulum, Logistic map, Period doubling, Lorentz model, Kepler problem and planetary orbits, Perihelion precession of mercury, Three body problem and effect of Jupiter on Earth; Iterative methods (Root Finding): Methods: Successive bisection, Newton Raphson, Secant Method; *Physical Problems:* Energy Eigenvalues of the square well potential, Kronig-Penny model.

Methods of Integration: Methods: Mid-point rule, Trapezoidal Rule, simpson's rule, errors; *Physical Problems:* First-order, second-order corrections in Perturbation theory, Magnetic field produced by the current; Partial Differential Equations: Methods: Finite difference method, Relaxation Method, Crank-Nicholson scheme, Shooting Method, Spectral Methods;*Physical Problems:* Solving Diffusion Equation, Wave Equation, Poisson equation.

Stochastic Simulations: Random numbers, Pseudo Random number generators, Distributions, Methods of generating random numbers following non-uniform distributions; transformation method and relaxation method. Monte-Carlo integration
Physical Problems: Random Walk and Diffusion, Cluster Growth Models, Percolation, Ising Model.

TEXTBOOKS/REFERENCES

1. Paul Devries and Javier Hasbun, *A First Course on Computational Physics*.

2. Nicholas Giordano and Hisao Nakanishi *Computational Physics* (2^{nd} Ed.), Prentice-Hall.

Partial List of Electives in Physics

1. FLUID DYNAMICS
2. NONLINEAR DYNAMICS
3. ADVANCED QUANTUM MECHANICS: MANY BODY THEORY
4. STATISTICAL FIELD THEORY
5. NON-EQUILIBRIUM STATISTICAL MECHANICS
6. ADVANCED MATHEMATICAL METHODS
7. EARLY UNIVERSE
8. ASTROPHYSICS
9. QUANTUM INFORMATION THEORY
10. PHYSICS AT THE NANO SCALE
11. QUANTUM THEORY OF FIELDS
12. GENERAL THEORY OF RELATIVITY AND COSMOLOGY
13. STRING THEORY

LABORATORY COURSES

PHY 112 Experiments in Mechanics [0031]

1. Moment bar
2. Simple & Variable-g Pendulums
3. Compound Pendulum
4. Newton's Laws of Motion
5. Centripetal Force
6. Conservation of Momentum
7. Ballistic Pendulum
8. Conservation of Energy
9. Sonometer
10. Melde's String
11. Projectile Motion

PHY 122 Experiments in electrodynamics [0031]

1. Potentiometer Internal Resistance of Cell
2. Magnetic field along the axis of Circular Coil

3. Deflection Magnetometer
4. Conversion of Galvanometer to Voltmeter
5. Ballistic Galvanometer Capacitance
6. Spot Galvanometer High Resistance
7. Diode Characteristics & Gates using Diodes
8. Diode Rectifiers
9. Zener Diode Voltage Regulator
10. Electronics using MultiSim and NI Interface

PHY 212 Experiments in Optics [0031]

1. Convex Lens
2. Concave Mirror
3. Spectrometer- Refractive index of Prism
4. Spectrometer Grating
5. Newton's Rings
6. Diffraction at Slits Single and Double
7. Spectrometer: i-d curve
8. Liquid Lens
9. Reflection Grating
10. Polarization Malus Law

PHY 222 Experiments on Heat and Thermodynamics [0031]

1. Joly's Bulb P vs. T at constant V
2. Newtons Law of Cooling
3. Specific Latent Heat of Steam
4. Thermal Conductivity of Rubber
5. Specific heat of a Solid Method of Mixtures
6. Specific heat of Liquid Joule's Calorimeter
7. Thermal conductivity - Lee's disc
8. Potentiometer Thermo emf
9. Stefan's Constant
10. Lorentz Number for Copper

PHY 315 Advanced Physics Experiments I [0093]

1. Viscosity of a Liquid - Oscillating Disc Method

2. Viscosity of Liquid Variable or Constant Pressure Head.
3. Torsion Pendulum Rigidity modulus of material of wire
4. Young's Modulus: Cornu's Method (Elliptical & Hyperbolic Fringes)
5. Spectrometer: $i - i'$ curve
6. Spectrometer Hartmann's formula (Find unknown wavelength)
7. Youngs modulus Optic Lever Mehtod
8. Surface Tension Capillary Rise (Water) Method, Capillary Dip (Mercury) Method and Quincke's Method (Mercury)
9. Beam Profile of Laser Divergance of Laser Beam
10. Diffraction by ultrasonic waves Velocity of Sound in Liquid
11. e/m - Thomsons Method
12. Dipole Moment of Organic Molecule
13. Fabrey-Perot Interferometer
14. Michelson's Interferometer
15. LCR circuit (Series and Parallel) Frequency Response and Value of Unknown L
16. AC Bridges Anderson, Maxwell, DeSauty, Owen
17. Photo-diode Characteristics (Intensity vs. Photo current, dark resistance of photo diode)
18. Transistor Characteristics (CE)
19. Transistor as a Switch and Amplifier
20. Voltage Controlled Oscillator (Transistor): Variation in frequency with control voltage
21. Voltage Controlled Oscillator (555 timer): Variation in frequency with control voltage
22. Colpit & Hartley Oscillators (Transistor)
23. Phase-shift & Wein-bridge Oscillators (Transistor)
24. Mono-stable Multivibrator (Transistor)
25. Bi-stable Multivibrator (Transistor)

PHY 325 Advanced Physics Experiments II [0093]

1. Velocity of light Foucolt's Method
2. Photo-electric Effect Characteristics of photoelectric emission (I-V for different wave lengths and different frequencies), Plancks Constant from Voltage-frequency curve
3. Thermal diffusivity of brass
4. Arc Spectrum Iron or Brass

5. Absorption Spectrum $KMnO_4$ or Iodine
6. Calibration of Secondary Thermometers
7. Thermal Relaxation of Bulb
8. X-ray spectrum analysis
9. Resistivity (4 probe Method) & Temp. Coefficient of Resistance of Copper
10. FET Characteristics and Amplifier using FET
11. SCR, Triac, Diac Characteristics
12. Op-Amp Inverting and Non-inverting amplifiers (Frequency Response)
13. Op-Amp Mathematical Tools (Addition, Integration, Differentiation)
14. Square, Triangular & Saw-tooth wave generators using Op-amp
15. Low-pass Signal Filter (First and Second Order) Frequency Response
16. High-pass Signal Filter (First and Second Order) Frequency Response
17. Band Pass and Band Reject Filters Frequency Response
18. Differential Amplifier using transistor CMRR, Frequency responses (Common and Diff. Modes)
19. Amplitude modulation Modulation index for different amplitudes of audio signal.
20. SR & JK Flip-flops
21. Decade Counters with seven segment Display
22. D/A Converter
23. Microprocessor programming Multiplication / Bubble sorting
24. Microprocessor programming - A/D Converter
25. Microprocessor programming - Stepper Motor

PHY 415 Advanced Physics Experiments III [0093]

1. Curie-Wiess Law of Dielectric Material
2. Zeeman Effect To verify the ratio of $_0/hc$ using Zeeman splitting in $6\,^3P_2$ and $7\,^3S_1$ states of mercury.
3. Nuclear Magnetic Resonance
4. Hall Effect
5. ESR spectrometer: g-factor of a sample
6. Band gap of a semiconductor
7. Magnetic susceptibility - Quincke's Method
8. $B - H$ Curve (Ferromagnet)
9. Noise fundamentals
10. Optical Pumping

11. Two slit Interference - one photon at a time
12. Damped-Driven Pendulum
13. GM Counter
14. Fiber Optics
15. Super Conductivity
16. Design new experiments (micro projects)

Interdisciplinary Courses

IDC 111 Mathematical Tools I [2023]

Preliminary Topics : Functions of several variables - partial differentiation. Cartesian, Spherical and Cylindrical coordinate systems: introduction and equivalence. Parametric representation of an equation. Introduction to Taylor's series with practical examples.

PRACTICAL COMPONENT : Introduction to MATHEMATICA. Importing/exporting formatted datasets. Plotting of functions and data in 2D, 3D; Plotting parametrically defined functions. Basic mathematical operations; symbolic differentiation of single and multi variable functions. Simple data fitting (e.g. polynomial, exponential functions etc), error estimation. Examples for Taylor series expansion, demonstration of convergence. Programming in MATHEMATICA, debugging and execution.

Vector Analysis : Review of vector algebra: addition, subtraction and product of two vectors - polar and axial vectors with examples; triple and quadruple product. Concept of Scalar and Vector fields. Differentiation of a vector w.r.t. a scalar - unit tangent vector and unit normal vector. Directional derivatives - gradient, divergence, curl and Laplacian operations and their meaning. Concept of line, surface and volume integrals. Statement of Gauss' and Stokes' theorems with physical examples. Gradient, divergence and curl in spherical polar and cylindrical coordinate systems.

PRACTICAL COMPONENT: Plotting vectors in 3D; algebraic operations, span and linear independence. Visualizing the plane determined by two vectors; determining the unit normal from vector product. Obtaining equation of the plane and parametric representation of the same. Plotting a system of simple contours and surfaces as a visual representation of scalar fields. Determining the gradient of a scalar field and graphical representation of the gradient as vectors. Visualization of various types of vector fields (divergent, rotational etc.) in 2D and 3D. Determination of divergence and curl of vector fields and their graphical representation. Real life scalar (temperature) and vector fields (static and rotating garden sprinkler, liquid vortex) and practical applications of the gradient, diver-

gence and curl.

Fourier Series : Fourier expansion statement of Dirichlets condition, analysis of simple waveforms with Fourier series. Introduction to Fourier transforms; the Dirac-delta function and its Fourier transform; other simple examples. Examples: Vibration of stretched strings- plucked and struck cases. Discrete Fouier transform, auto correlation and cross correlation. Convolution Theorem and Parseval Theorem.

PRACTICAL COMPONENT: Demonstration of Fourier series representation for simple waveforms (e.g. Square, triangular, saw tooth). Nyquist sampling, Discrete Fourier Transform for sine, sine-Gaussian, frequency modulated sine. Inverse discrete Fourier transform; spectral analysis, frequency resolution. Demonstration of Parseval theorem.

Complex numbers and functions : Arithmetic operation, conjugates, modulus, polar form, powers and roots; Derivative; analytic function; Cauchy-Riemann equation, Laplace equation- Harmonic functions; Complex integration: Cauchys integral theorem (without proof), Cauchys integral formula.

PRACTICAL COMPONENT: Plotting of familiar functions in the complex plane

TEXTBOOKS

1. G. B. Arfken and H. J. Weber, Mathematical Methods for Physicists, 6^{th} Ed., Academic Press 2010.
2. E. Kreyszig, Advanced Engineering Mathematics, 8th Edition Wiley India Pvt Ltd, 2006.
3. Murray R. Spiegel, Schaum's Outlines Vector Analysis, Tata Mcgraw Hill 2009.
4. Murray R. Spiegel, Schaum's Outlines Fourier Analysis with Applications to Boundary Value Problems Tata Mcgraw Hill 2006.
5. Murray R. Spiegel, Seymour Lipschutz, John Schiller, Dennis Spellman, Schaum's Outlines Complex Variables, 2^{nd} Edition, Tata Mcgraw Hill 2009.
6. J. W. Churchill and R. V. Brown, Complex Variables and Applications Mcgraw-Hill 2008.
7. Stephen Wolfram, The MATHEMATICA Book, 5th Edition.

IDC 121 Mathematical Tools II [2023]

Matrices: Review of Matrices (already covered in MAT 111) Matrix operations, Hermitian adjoint and inverse of a matrix; Hermitian, orthogonal,

and unitary matrices; Eigenvalue and eigenvector (for both degenerate and non-degenerate cases); Similarity transformation; diagonalisation of real symmetric matrices.

PRACTICAL COMPONENT: Introduction to MATLAB. Data handling in MATLAB. 2D Matrix operations and manipulation; Addition, subtraction, inverse, transpose, multiplication, element by element operations. Check whether given matrix is symmetric, hermitian, unitary, orthogonal, antisymmetric, singular. Diagonalization and Eigen-value problem. Regression Analysis.

Ordinary Differential Equations: First order differential equations: Basic concepts and ideas; separable differential equations, Integrating factors, linear differential equations; Second order linear differential equations homogenous equations with constant coefficients, Linear Independence of solutions-Wronskian, Non-homogenous equations general solution. System of Linear ODEs. Laplace Transforms.

PRACTICAL COMPONENT : Numerical differentiation. Euler's method to solve ODEs. First ODE (e.g. free particle under gravity, evolution of chemical concentration in a reaction, motion in viscous media/magnetic field); Second ODE (harmonic oscillator with/without damping); First order coupled ODE (Predator-Prey problem). Solution of a system of linear ODE. Programming in MATLAB.

Partial Differential Equations: Solution by the method of separation of variables; Laplace's equation and its solution in Cartesian, spherical polar (axially symmetric problems), and cylindrical polar ('infinite cylinder' problems) coordinate systems.

TEXTBOOKS

1. G. B. Arfken and H. J. Weber, Mathemetical Methods for Physicists, 6^{th} Ed., Academic Press 2010.
2. E. Kreyszig, Advanced Engineering Mathematics, 8th Edition Wiley India Pvt Ltd, 2006.
3. Richard Bronson, Gabriel Costa, Schaum's Outlines Differential Equations, 3rd Edition Mcgraw-hill 2009.
4. C. Edwards and D. Penny, Elementary Differential Equations with Boundary value Problems, 5th Edition Prentice Hall 2007.
5. Murray R. Spiegel, Schaum's Outlines Fourier Analysis with Applications to Boundary Value Problems Tata Mcgraw Hill 2006.

IDC 211 Biochemistry [3103]

Introduction to biochemistry.

Nucleic acids: ribose, deoxyribose , purines, pyrimidines, nucleosides, nucleotides, structures of DNA and RNA, conformation.

Proteins: amino acids and their classification, protein structures primary, secondary, tertiary, quaternary Domains and folds, hydrophobic effect and protein folding, secondary structure elements, backbone conformations (amino acid to Ramachandran plot), helices in domains and motifs, beta structures, active sites & binding pockets, protein sequence comparison.

Carbohydrates: linear and cyclic forms of monosaccharides, oligo- and polysaccharides, glycoconjugation of proteins and lipids, and functions of carbohydrates.

Lipids & Membranes: Lipid structures, triglycerides, fatty acids and phospholipids, micelles, planar bilayers, vesicles, lipoproteins, lipid-binding protein domains, cell membranes and compartments, membrane proteins, membrane transport, thermodynamic hypothesis.

Central dogma of life and modifications to the central dogma: replication, transcription, triplet code, translation, reverse transcription.

Biochemical thermodynamics: enthalpy, entropy, free energy, chemical potential, and redox reactions.

Enzymes: Michaelis-Menten kinetics, allosteric enzymes, enzyme catalysis mechanisms, example of protease.

IDC 221 Principles and Applications of Spectroscopy [3103]

Introduction: Electromagnetic radiation, absorption, emission and scattering, Einstein A and B coefficients, lasers, basic elements of practical spectroscopy, signal to noise ratio, resolving power; Atomic Spectroscopy: Spectra of hydrogen atom, Bohr's theory, angular momentum, Sommerfeld theory, the hydrogen atom and one electron spectra, selection rules, many electron atoms, coupling of orbital and spin angular momenta, term symbols, fine and hyperfine structure, Zeeman and Stark effects.

Rotational Spectroscopy: Rigid rotor as a model system for rotations, rotational angular momentum, energy levels, selection rules, structure determination from rotational constants, isotope effects, instrumentation; Vi-

brational Spectroscopy: Morse oscillator, Harmonic oscillator as a model system for vibrations, diatomic molecules, vibrational selection rules, dissociation energies, instrumentation.

Raman Spectroscopy: Light scattering and Raman effect, classical model for scattering, Stokes and anti-Stokes lines, polarizability, instrumentation Spin Resonance Spectroscopies: nuclear spin and electron spins, effect of applied external fields, Nuclear Magnetic Resonance (NMR) spectroscopy, Electron Spin Resonance (ESR) spectroscopy, basic principles and examples, instrumentation Mossbauer Spectroscopy: Principles and Applications, instrumentation.

TEXTBOOKS/REFERENCES

1. J Michael Hollas, *Modern Spectroscopy*, John Wiley & Sons.
2. C N Banwell and E M McCash, *Fundamentals of molecular spectroscopy*.

Faculty

SCHOOL OF BIOLOGY

1. Dr. Srinivasula Srinivasa Murty, Ph.D. (Banaras Hindu University)
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3. Dr. Tapas Manna, Ph.D. (Bose Institute, Kolkata)
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July	August	September	October	November
1 Mon	1 Thu Regn: S3-S9	1 Sun	1 Tue	1 Fri
2 Tue	2 Fri Regn: S1, RC: S3-S9	2 Mon 1st Mid Sem	2 Wed Gandhi Jayanti	2 Sat Diwali
3 Wed	3 Sat Orientation: S1	3 Tue 1st Mid Sem	3 Thu	3 Sun
4 Thu	4 Sun	4 Wed	4 Fri	4 Mon
5 Fri	5 Mon RC: S1	5 Thu	5 Sat	5 Tue
6 Sat	6 Tue	6 Fri	6 Sun	6 Wed
7 Sun	7 Wed	7 Sat	7 Mon	7 Thu
8 Mon	8 Thu	8 Sun	8 Tue	8 Fri
9 Tue	9 Fri Id-ul-Fitr (Ramzan)	9 Mon Vinayaka Chaturthi	9 Wed	9 Sat
10 Wed	10 Sat	10 Tue	10 Thu	10 Sun
11 Thu	11 Sun	11 Wed	11 Fri 2nd Mid Sem	11 Mon
12 Fri	12 Mon	12 Thu	12 Sat 2nd Mid Sem	12 Tue
13 Sat	13 Tue	13 Fri	13 Sun Dussehra	13 Wed
14 Sun	14 Wed	14 Sat	14 Mon 2nd Mid Sem	14 Thu Muharram
15 Mon	15 Thu Independence Day	15 Sun	15 Tue	15 Fri CE for Sem 3,5,7
16 Tue	16 Fri	16 Mon Onam	16 Wed Id-ul-Zuha (Bakrid)	16 Sat
17 Wed	17 Sat	17 Tue	17 Thu	17 Sun Guru Nanak Jayanti
18 Thu	18 Sun	18 Wed	18 Fri	18 Mon S1 S3 S5-S9 RC TE TE
19 Fri	19 Mon	19 Thu	19 Sat	19 Tue S1 S3 S5-S9 RC TE TE
20 Sat	20 Tue	20 Fri	20 Sun	20 Wed S1 S3 S5-S9 RC TE TE
21 Sun	21 Wed	21 Sat	21 Mon	21 Thu S1 S3 S5-S9 CE TE TE
22 Mon Repeat Exams Begin	22 Thu	22 Sun	22 Tue	22 Fri S1 S3 S5-S9 TE TE TE
23 Tue	23 Fri	23 Mon	23 Wed	23 Sat S1 S3 S5-S9 TE TE TE
24 Wed	24 Sat	24 Tue	24 Thu	24 Sun
25 Thu	25 Sun	25 Wed	25 Fri	25 Mon S1 S3 S5-S9 TE TE TE
26 Fri Repeat Exams End	26 Mon	26 Thu	26 Sat	26 Tue S1 S3 S5-S9 TE TE TE
27 Sat	27 Tue	27 Fri	27 Sun	27 Wed S1 S3 S5-S9 TE TE TE
28 Sun	28 Wed	28 Sat	28 Mon	28 Thu S1 S3 S5-S9 TE TE TE
29 Mon Regn Int..Ph.D.	29 Thu	29 Sun	29 Tue	29 Fri Semester Ends
30 Tue Orientation Int. Ph.D.	30 Fri	30 Mon	30 Wed	30 Sat
31 Wed Regn Ph.D.	31 Sat 1st Mid Sem		31 Thu	