INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH THIRUVANANTHAPURAM

An autonomous institution under the

Ministry of Human Resource Development, Government of India

GUIDE BOOK OF REGULATIONS AND CURRICULUM FOR THE BS-MS DUAL DEGREE PROGRAMME

2015-16

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 six IISERs established by MHRD are at Bhopal, Kolkata, Mohali, Pune, Thiruvananthapuram and Tirupati.

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.

Contents

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 – November.
  (b) Vasanth Semester : January – April.

- The first two years (i.e. the first 4 semesters) will consist of FOUNDATION/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.
- To register for a course ALL prerequisites must be successfully completed [1].

[1] refer page 4, clause 2 of Essentials for Completing Courses

- 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 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. Marks will be given on completion of each experiment 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

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

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W - for "Withdrawn"

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

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 FOUNDATION/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 have 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

1. Students are expected to attend all the classes. Students with overall 80% attendance or above will only be permitted to write the end semester examination. Attendance will be recorded in the prescribed book in every class and attendance percentage will appear in the grade transcript.
2. To register for any course a student must have completed ALL prerequisite courses (if any) with a D grade or better.
3. A student with an F grade in a course may be given a repeat final examination. An F grade may be improved at best to a D grade as a result of the repeat final exam.

   Under-performing students from semesters 1-4 may be given remedial classes during semester break before the repeat final examination.
4. Repeat of a course is not permitted if the student has obtained a grade D or above in the same course.

5. The incomplete grade I is a *transitional* grade which will be given to the students who miss the end semester examinations under exceptional circumstances (e.g. serious medical reasons) as determined by the course instructor and the BS-MS coordinator in consultation with the School coordinator (if applicable) and approved by the Dean (Academics).

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

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

   Absence in the make-up examination will automatically lead to zero marks in that examination and the final grade in that course will be determined based on the other examinations taken in that course.

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

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

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

8. If a student does not clear a FOUNDATION/CORE course even after writing (or skipping) 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 passed by the student, it is treated as a *backlog* in the student's records. Both the grades, the new grade and the previous F grade, will appear in the grade transcripts.

9. An F grade obtained in a course will contribute to the CGPA until

   (a) a course with the same course number is completed with a D grade or better (applicable for foundation and core courses) or
   (b) substituted with an alternative/same course and completed with a D grade or better (applicable *only* for minor/elective courses) or
   (c) ALL Degree Requirements[2] are satisfied.

10. 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.

11. A student who has more than two F and/or W 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 W grades.

Ceiling of Credits in Semesters 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 adviser and school coordinator (in which they are majoring) regarding registration of suitable courses

[2] see page 4

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.

Removal from the Rolls

Any one of the following circumstances will lead to removal from the rolls:

- Failure to maintain the minimum SGPA of 4.0 in any two consecutive semesters will lead to automatic removal of the student from the rolls.
- Failure to clear any FOUNDATION/CORE course after repeating the same course *once* will lead to the removal of the student from the BS-MS Programme.
- ALL FOUNDATION/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.
- A student may also be removed from the rolls as a result of disciplinary action for serious misconduct and/or violation(s) of the code of conduct of the institute.

INSPIRE/KVPY Fellowship

The Department of Science and Technology Government of India has instituted the INSPIRE Fellowship available to each student of IISER.

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.

Institute may provide financial subsistence to students from SC/ST who are not able to retain INSPIRE/KVPY scholarship as per applicable provisions.

Course Feedback

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

Re-evaluation of End Semester Examination Answer Sheets

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

Project Evaluation

- The major project work is carried out in two stages, each spread over a semester. At the end of ninth 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 Section.
- 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 time period, 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 Grade Card

OFFICIAL GRADE CARD

Name of Student : XXX Roll Number : IMSXX00X Date of Issue : XX-XXX-20XX
Graduating class : 20XX - Dual degree BS-MS programme PAGE 1 of 1
XXX has attended 2 semesters of classes at IISER Thiruvananthapuram

Varsha 20XX		Credits	Grade
BIO 111	Introductory Biology	3	B
BIO 112	Introductory Biology Lab	1	B+
CHY 111	Atomic Structure and Chemical Bonding	3	B
CHY 112	Chemistry Lab I	1	B+
HUM 111	Functional English	1	B
IDC 111	Mathematical Tools	3	B
MAT 111	Introduction to Algebra	3	B
PHY 111	Mechanics I	3	C
PHY 112	Physics Lab I	1	A
		SGPA: 6.89	

Vasanth 20XX			
BIO 121	Introductory Physiology	3	C+
BIO 122	Introductory Physiology Lab	1	B+
CHY 121	Chemistry of Elements	3	C
CHY 122	Chemistry Lab II	1	B+
HUM 121	Humanities	1	B
IDC 121	Mathematical Tools II	3	A
MAT 121	Introductory Analysis I	3	C
PHY 121	Electrodynamics I	3	C
PHY 122	Physics Lab II	1	B+
		SGPA: 6.37	

Total credits completed: 38 CGPA: 6.63

Dean (Academics) Grade Card No: XXXXXXXXX

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 will notify parents/guardians if a student violates the Code of Conduct. 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 adviser/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 (with one woman and/or SC-ST observer if the accused student(s) belong to the same community), 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, revoking of awarded degrees, suspension for a certain period or even permanent expulsion from the Institute.

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

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

Disciplinary Action for Malpractices in Research:

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

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

Plagiarism includes, without citation, the appropriation of 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 Code of Conduct, 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 Holidays: Closed
   b. During Exam Week: 9 AM to 10 PM.
   c. Circulation Timing:
      Monday to Friday: 9.15 AM to 5.15 PM
      Saturday: 9 AM to 12 Noon
2. Membership: All registered BS-MS students are eligible for membership in the institute library.
3. BS-MS students can borrow maximum 4 books at a time for 2 weeks, provided they do not have any overdue book. (Note: Some books may have a shorter loan period depending on the demand)
4. Users must leave their bags and other belongings outside the Library. Only notebooks and papers are allowed inside the library. Borrowed books are allowed to be taken to the library for return/renewal only. All items taken out of the library (including personal items, if any) are to be produced for verification by the check point staff engaged in front of the library.
5. Students must carry their identity cards inside the library and it must be produced whenever asked for. Identity card is mandatory for borrowing books from the Library.
6. Strict silence has to be maintained by all users in the library.
7. Use of mobile phones, laptops, consumption of food and drinks are strictly prohibited inside the library.
8. Use of the user PC kept inside the library is allowed only for accessing library catalogue, e-journals, e-books and academic databases.
9. Return of book is mandatory before the due date. A fine of Rs. 1/- per day per book for the first week of delayed return and Rs. 10/- per day per book thereafter will be levied. Renewal of a book is possible only if there is no pending reservation against it. A book may be recalled any time before the due date, if it is urgently required by another member. A late fee of Rs. 10/- per day per book will be imposed for the non-compliance with the requirement.

10. Any book, including reference books can be borrowed for overnight reference, at the closing time of the library and to be returned at 9 AM on the next working day. Only one book can be borrowed for overnight reference. A late fee of Rs. 50/- per day per book for the delayed return of such book will be charged.
11. Mutilation of books in any form (e.g. underlining, writing on pages, tearing off pages, damaging the binding etc.) will lead to a heavy fine or even replacement of the book. Before borrowing a book users should ensure the condition of the book and bring to the notice of the library staff, if any mutilation is found.
12. Members who lose/mutilate library books are liable to replace it with its latest edition along with a penalty of 20% of the total cost of the book. All such replaced books must be of the latest edition. If the book is part of a set or series they may be called upon to replace the whole set or series. In case of the lost books is untraceable in market or out of print Library Committee reserves the right to decide appropriate penalty
13. BS-MS students must return all the books they borrowed before they go for vacation.
14. Users should obey the Library Rules and Regulations. Violation of rules and any act of misbehaviour will be brought to the notice of the Library Committee Chair, and will lead to strong disciplinary action.

HOSTEL REGULATIONS

1. 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 to be recorded in the register kept with the matron/security in the Hostel.
2. ALL students must return to their respective hostels by 10.00 pm. Students CAN NOT leave the hostels after 10 PM. Parents of the defaulters shall be contacted and the local police might be informed in case such activities happen without prior permission of the warden.
3. Leaving the hostel for a day or longer need prior permission from the faculty adviser 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 Of-

fice 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.

4. 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.
5. 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.
6. Any kind of loud noise in the rooms, corridors and premises of the hostel, especially during night, is prohibited.
7. Students are required to take care of their personal belongings, keep the respective rooms clean and the hostel premises tidy.
8. Students are required to take utmost care for the hostel furniture, TV, washing machines, building structure, electrical fittings etc.
9. Students should strictly avoid getting into arguments with fellow hostellites, localites and security officers/matrons of the hostel.
10. Cooking inside the rooms is strictly prohibited.
11. Guests are not allowed in hostel rooms.
12. In case of any emergency (illness, accidents etc), contact the concerned warden.
13. 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.
14. Please take care of your personal belongings.
15. Anti-ragging regulations of the institute have to be strictly followed in the hostels too.
16. Use of drugs/alcoholic beverages/tobacco products in the hostels is strictly prohibited. Smoking in public is a punishable offence.

Violation of any of the above rules shall make the student liable to disciplinary action by the Institute.

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 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 per week
T	:	Tutorial hours per week
P	:	Practical hours per week
C	:	Credits

Subject codes

BIO : Biological Sciences
CHY : Chemical Sciences
MAT : Mathematical Sciences
PHY : Physical Sciences
IDC : Interdisciplinary Studies
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	Single Variable Calculus	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	Humanities - I	0	1	0	1	HUM 121	Humanities - II	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	Multivariable Calculus	3	1	0	3	MAT 221	Introduction to Probability and 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 - III	0	1	0	1	HUM 221	Humanities - IV	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)* + 4 (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 limited. 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 FOUNDATION/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

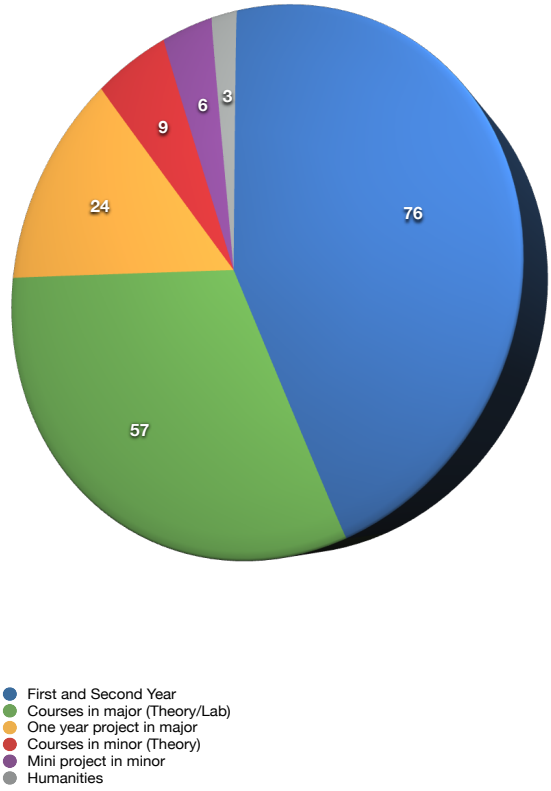
SEMESTER 9

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	Developmental Biology	3	0	0	3		BIO 321	Neurobiology	3	0	0	3
BIO 312	Biophysics	3	0	0	3		BIO 322	Advanced Evolutionary Ecology	3	0	0	3
BIO 313	Plant Molecular Genetics	3	0	0	3		BIO 323	Advanced Cell Biology	3	0	0	3
BIO 314	Genomics	3	0	0	3		BIO 324	Biostatistics	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	Immunology	3	0	0	3		BIO 421	Advanced Molecular Biology	3	0	0	3
BIO 412	Microbiology	3	0	0	3		BIO 422	Bacterial Genetics	3	0	0	3
BIO 413	Advanced Biochemistry	3	0	0	3		BIO 423	Structural Biology	3	0	0	3
BIO 414	Advanced Physiology	3	0	0	3		BIO 424	Mathematics and Systems Biology	3	0	0	3
BIO 415	Advanced Biology Lab-III	0	0	9	3		BIO 4201	Elective I	3	0	0	3
Total		**12**	**0**	**0**	**15**		**Total**		**15**	**0**	**0**	**15**
Cumulative credits at the end of fourth year: 136												
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: 163												

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
CHY 3101	Elective I	3	0	0	3						
Total		**15**	**0**	**9**	**18**	**Total**		**12**	**0**	**9**	**15**
Cumulative Credits at the End of Third Year: 110											
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 and Photochemistry	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 IV	3	0	0	3
CHY 415	Advanced Physical Chemistry Lab	0	0	9	3						
CHY 4101	Elective II	3	0	0	3						
CHY 4102	Elective III	3	0	0	3						
Total		**18**	**0**	**9**	**21**	**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 143											
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 V	3	0	0	3						
Total		**12**	**0**	**0**	**12**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 170											

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	Abstract Algebra	3	0	0	3	MAT 322	Measure Theory and Integration	3	0	0	3
MAT 313	Linear Algebra	3	0	0	3	MAT 323	Galois Theory and Commutative Algebra	3	0	0	3
MAT 314	Numerical Analysis	3	0	0	3	MAT 324	Theory of Ordinary Differential Equations	3	0	0	3
MAT 315	Number Theory and Cryptography	3	0	0	3	MAT 325	General Topology	3	0	0	3
Total		**15**	**0**	**0**	**15**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Third Year: 106											
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	Probability Theory & Random Processes	3	0	0	3
MAT 412	Analysis on Manifolds	3	0	0	3	MAT 422	Differential Geometry	3	0	0	3
MAT 413	Partial Differential Equations	3	0	0	3	MAT 4201	Elective II	3	0	0	3
MAT 414	Programming and Data Structures	2	0	2	3	MAT 4202	Elective III	3	0	0	3
MAT 4101	Elective I	3	0	0	3						
Total		**14**	**0**	**2**	**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**
MAT 511	Major Project	9	0	0	9	MAT 521	Major Project	15	0	0	15
MAT 5101	Elective IV	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 BS-MS graduation requirement of 175 credits, students may need to take minor or additional courses.*

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 Section

Application form for choosing Major **Deadline: XX/XX/XXXX**

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.I agree to the allotment of major based on my preferences and academic standing upto 4th semester.

Date : (Signature of the Student)

For Office Use:

Choice in order of Preference	Major Subject	Sem-IV Grade		Subject GPA	CGPA up to 4th Sem	Index Point
		Theory	Lab			
First Choice						
Second Choice						
Third Choice						
Fourth Choice						

Biology Syllabus

THEORY COURSES

BIO 111 Introductory Biology [3103]

Introduction to biology: What is life? The basic unit of life, Hierarchical levels of organization in Biology, "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 - Sizing up *E. coli*.

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 semiconservative replication, bacterial chemotaxis); Yeast (rise of biochemistry); Flies (Drosophila and Modern Genetics, Homeotic mutations); Mice, Arabidopsis & Men; Exotica (Squid Axon, C. elegans).

TEXTBOOKS

1. Campbell and Reece, *Biology*, 7th Ed, Pearson-Benjamin Cummins
2. Raven, Johnson, Losos, Mason, Singer, *Biology*, 8th Ed. Mcgraw Hill.
3. John Kuriyan, Boyana Konforti and David Wemmer, *The Molecules of Life : Physical and Chemical Principles*. 1st Ed.
4. Rob Phillips, Jane Kondev, Julie Theriot, *Physical Biology of the Cell*, Garland Science.

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, insitu 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 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 312 Biophysics [3003]

Section 1- (Molecular biophysics, 10 lectures): Chemical forces translation and rotation, biomolecules as machines work, power and energy, thermal, chemical and mechanical switching via biomolecules. Organization of biomolecules self assembly and thermodynamics, electromagnetic effect on biomolecules ion channels and nerves, chemical kinetics, biological reactions and interactions, introduction to protein folding.

Section 2 - (Cellular biophysics, 22 lectures) Topics: Order of magnitude physics applied to biology, construction plans for cells and organisms, time keeping at many scales, model systems across the scales, random walks, rate equations and dynamics of the cell, network organization in space and time.

Section 3 - (Membranes and Life, 3 lectures) Membrane mechanicsmodels and measurements. Going from atomistic to continuum ideas.

Section 4 - (Beam theory and cytoskeleton, 7 lectures) The mechanics associated with cellular architecture. Cellular skeleton and extracellular matrices.

Section 5 - (Physical features of cell migration, 2 lectures) Integrating ideas from intra- and extra-cellular structures to understand the role of forces in cell migration.

Section 6 - (Biophysical techniques, 7 lectures) Topics: Light in biology, microscopy techniques, measuring forces in bio-molecules. Demonstration labs.

Section 7 - (Presentations of topics by students, 4 lectures) Reading assignments and their presentations.

BIO 313 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 314 Genomics [3003]

Model genomes.

Scale of genome variation: mutations, SNPs, in-dels, structural variation, ploidy changes.

Methods to study genomes: PCR, microarrays, next generation sequenc-

ing 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 321 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 322 Advanced 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 323 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 324 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 411 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 412 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 413 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 414 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.

BIO 421 Advanced Molecular Biology [3003]

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

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

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

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

Non-coding RNA: Biogenesis and its function.

Genome instability: Aneuploidy, haploidy and polyploidy.

Recombinant DNA technology and molecular cloning.

BIO 422 Bacterial Genetics [3003]

PREREQUISITE

1. BIO 412 - 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 423 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 matrices -examples.

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

Structural Biology methods for determination of macromolecular struc-

tures:

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 424 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.

Partial List of Electives in Biology

1. Stem cells and regenerative medicine
2. Sensory ecology of behaviour
3. Advanced topics in ecology, evolution and behaviour (primary literature and book chapter discussion)
4. Biodiversity and field biology
5. Advanced immunology
6. Prokaryotic development
7. Cancer biology
8. Special topics in genetics and chromosome biology
9. Treatise on molecular structural biology
10. 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 Introductory Physiology Lab [0031]

Plant Physiology:

1. Measurement of water potential of onion peel/Rhoeo peel by Plasmolytic method
2. Analysis of Hills reaction by DCPIP/Ferricyanide reduction
3. Estimation of stomatal density and stomatal index in diverse plant species
4. Physiological identification of CAM plants
5. Identification and biochemical characterization of *Rhizobium* bacteria from the root nodules of various leguminous plants
6. Plant hormones: Bioassay for Gibberellin using Wheat /Maize seeds

Animal Physiology:

1. Genomic DNA extraction from animal cells, Drosophila samples: amplification of *actin, myosin heavy chain* and *insulin-like peptide* genes
2. RNA extraction from Drosophila samples and perform an RT-PCR using specific primers for *insulin-like peptide (dilp)* gene and run an agarose gel
3. Protein extraction from fed and starved Drosophila samples and SDS-PAGE analysis for total protein levels

4. Estimation of triglyceride levels from Drosophila samples after starvation
5. Estimation of feeding in Drosophila samples after 12 hours of starvation

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]

Kinetic Theory of Gases:
Revision of Gas Laws, Ideal Gas Equation of State, Kinetic Theory, Interpretation of Pressure, Velocity distribution, Maxwell's distribution of speed, average, most probable and rms speed. Gas effusion, molecular collisions, mean free path. Transport phenomena, diffusion, time evolution of concentration gradient.

Real Gases:
Van der-Waals equation of state, virial equation of state, critical constants, liquification of a gas, compressibility factor, Boyle temperature, law of corresponding states, Fugacity.

Molecular Interactions:
Electric dipole moment and molecular polarizability, interactions between molecules; ion-ion, ion-dipole, dipole-dipole, dipole-induced dipole, induced dipole-induced dipole, quadrupolar interactions, dispersion interactions and hydrogen bonding.

Review of Laws of Thermodynamics:
Gibbs Energy and Helmholtz energy, review of Maxwell equations, Gibbs energy of a reaction mixture. Expressing chemical equilibrium in terms of chemical potential. Gibbs free energy changes in chemical reaction, equilibrium constants.

Ideal and Real Solutions:
Colligative properties (elevation of boiling point, depression of freezing point and osmotic pressure), binary solutions; Phase Diagrams: Phase rule and two component systems, phase stability and transitions, Clausius-Clayperon equation, liquid-vapour interface; Le-Chateliers principle, phase transformation of substances, chemical potential; vapour pressure diagram, temperature composition diagram, fractional, azeotropic and steam distillations and their importance in organic chemistry.

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 reac-

tions.

Electrochemistry:
Thermodynamic properties of ions in solutions, Debye Huckel theory, Nerst equation, standard electrode potential, electrochemical series, redox reactions, EMF and free energy.

TEXTBOOKS/REFRENCES

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 coordina-

tion 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: Blackbody radiation, photoelectric effect, spectral emissions from atoms, dual nature of light and matter, Schrödinger equation and its analogy with the classical wave equation, postulates

of quantum mechanics, wave functions and requirements for an acceptable wave function, operator formalism, eigenfunctions and eigenvalues, expectation values, Hermitian operators, measurement, superposition of states, commuting operators, uncertainty 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, quantum tunneling and scattering, simple harmonic oscillator, particle on a ring, particle on a sphere, angular momentum, hydrogen atom problem, atomic orbitals.

The Variation Method: Rayleigh-Ritz method, simple examples like hydrogen and helium atoms, the H_2^+ molecule-ion, LCAO-MO, molecular orbitals for diatomic molecules, Huckel theory. 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, degenerate perturbation theory.

Many Electron Atoms: The independent electron approximation, simple products and electron exchange symmetry, Slater determinants and Pauli principle, Hartree and Hartree-Fock methods, the self-consistent field method, Slater type orbitals, Gaussian type orbitals, basis sets.

TEXTBOOKS/REFRENCES

1. J. P. Lowe and K. A. Peterson, *Quantum Chemistry*, 3^{rd} Ed., Elsevier.
2. I. N. Levine, *Quantum Chemistry*, Prentice Hall.
3. Atkins and Friedman, *Molecular Quantum Mechanics*, Oxford University Press.
4. F. L. Pilar, *Elementary Quantum Chemistry*, Dover Publications.
5. Henry Eyring, John Walter and G. E. Kimball, *Quantum Chemistry*, John Wiley and Sons.
6. Thomas Engel and Reid, *Quantum Chemistry and Spectroscopy*, Prentice Hall.

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.

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. J. March, *Advanced Organic Chemistry*, 5^{th} Ed., John Wiley and Sons, 1992.

2. E. L. Eliel, *Stereochemistry of Carbon Compounds*, Tata McGraw-Hill Edition 1975, 38^{th} reprint 2008.
3. D. Nasipuri, *Stereochemistry of Organic Compounds-Principle and Applications*, 2^{nd} Ed., New Age International Publishers, 2007.
4. P. S. Kalsi, *Stereochemistry-Conformation and Mechanism*, 7^{th} Ed., New Age International Publishers, 2008.

CHY 314 Instrumental Methods [3003]

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

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

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

TEXTBOOKS/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* 2nd Ed., New Age International Publication (2000).
9. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models if Inorganic Chemistry*, 3rd Ed., Wiley (1994).
10. W. K. Li, G. D. Zou and T. C. W. Mak, *Advanced Structural Inorganic Chemistry*, Oxford Science Publication (2008).

CHY 322 Advanced Molecular Spectroscopy [3003]

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

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

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

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

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

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

TEXTBOOKS/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.

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, classifica-

tion 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*, 2^{nd} Ed., Cambridge University Press (1987).
3. L. E. Smart and E. A. Moore, *Solid State Chemistry: An introduction*, 3^{rd} Ed., Taylor and Francis, 2010 (Indian Ed.)
4. P. A. Cox, *The Electronic Structure and Chemistry of Solids*, Oxford Science Publications (1987).
5. D. Jiles, *Introduction to the Electronic Properties of Materials*, 2^{nd} Ed., 2010, Nelson Thornes Ltd. (Indian Ed.)
6. G. Gottstein, *Physical Foundations of Materials Science*, Springer (2004).

SUGGESTED READING

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

3. S. Elliot, *The Physics and Chemistry of Solids*, Wiley India (1998).

CHY 412 Advanced Chemical Kinetics and Photochemistry [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 chem-

ical 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

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

1. L. N. Childs, *A Concrete Introduction to Higher Algebra*, Springer, 2009.
2. S. Kumaresan, *Linear Algebra : A Geometric Approach*, Phi Learning, 2009.

REFERENCES

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

MAT 121 Single Variable Calculus [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

1. T. M. Apostol, *Calculus*, vol 1, 2nd ed., Wiley, 2007.
2. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 4th ed., Wiley, 2011.

REFERENCES

1. S. Lang, *A first course in Calculus*, 5th ed., Springer India, 2006.
2. W. Rudin, *Principles of Mathematical Analysis*, 3rd ed., McGraw Hill India, 1953.
3. M. Spivak, *Calculus*, Publish or Perish, 2008.
4. J. Stewart, *Calculus: Concepts and Contexts*, 3rd ed., Thomson Brooks/Cole, 2005
5. T. Tao, *Analysis I*, Hindustan Book Agency, 2006.

MAT 211 Multivariable Calculus [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.

Differentiating under the integral sign: Leibniz' formula, Taylor's formula, Mean Value theorems.

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, Fubini-Tonelli Theorem, 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

1. T. M. Apostol, *Calculus*, vol. 2, 2nd ed., Wiley (India), 2007.
2. S. Lang, *Calculus of several variables*, 3rd ed., Springer 1987.

REFERENCES

1. V. Zorich, *Mathematical Analysis I*, Springer 2004.
2. V. Zorich, *Mathematical Analysis II*, Springer 2004.

MAT 221 Introduction to Probability and 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

1. R. V. Hogg, J. McKean and A. T. Craig, *Introduction to Mathematical Statistics*, Pearson, 7th ed., 2012
2. S. Ross, *Introduction to Probability and Statistics for Engineers and Scientists*, 3rd ed., Elsevier, 2004.

REFERENCES

1. C. M. Grinstead and J. L. Snell, *Introduction to Probability*, 2nd ed., American Mathematical Society, 1997.
2. S. Ross, *A first course in Probability*, 8th ed., Prentice Hall, 2009.
3. S. Ross, *Introductory Statistics*, 2nd ed., Elsevier (India), 2006.

MAT 311 Real Analysis [3003]

Zorn's lemma, Axiom of choice, 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. T. M. Apostol, *Mathematical Analysis*, 2nd Edition, Addison Wesley, 1974.
2. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 4th Edition, Wiley, 2011.
3. R. M. Dudley, *Real Analysis and Probability*, Cambridge University Press, 2002.
4. S. R. Ghorpade and B. V. Limaye, *A Course in Calculus and Real Analysis*, Springer, 2006.
5. R. R. Goldberg, *Methods of Real Analysis*, 2nd Edition, Wiley, 1976.
6. S. Lang, *Undergraduate Analysis*, 2nd Edition, Springer, 1996.

7. W. Rudin, *Principles of Mathematical Analysis*, 3rd Edition, McGraw- Hill, 1976.
8. T. Tao, *Analysis I*, Hindustan Book Agency, 2006.

MAT 312 Abstract Algebra [3003]

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 313 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.

LU decomposition, cyclic decomposition, Matrix norms, positive definite matrices, 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, Sylvester's law of inertia, Sylvester's criterion for positive definite matrices, Hom, Tensor products, Bilinear forms.

TEXTBOOKS/REFERENCES

1. S. Axler, *Linear Algebra Done Right*, Springer, 1997.
2. W. H. Greub, *Linear Algebra*, 4th ed., Springer, 1981.
3. W. H. Greub, *Multilinear Algebra*, 2nd ed., Springer, 2013.
4. I. N. Herstein, *Topics in Algebra*, 2nd Edition, Wiley and Sons, 1996.
5. K. Hoffman and R. Kunze, *Linear Algebra*, 2nd edition, Pearson Education, New Delhi, 2006.
6. C. D. Meyer, *Matrix Analysis and Applied Linear Algebra*, SIAM, 2001.

MAT 314 Numerical Analysis [3003]

Roundoff Errors and Computer Arithmetic. Interpolation: Lagrange Interpolation, Divided Differences, Hermite Interpolation, Splines. Numerical Differentiation, Richardson Extrapolation. Numerical Integration: Trapezoidal, Simpsons, Newton-Cotes, Gauss quadrature, Romberg integration, Multiple integrals.

Solutions of Linear Algebraic Equations: Direct Methods, Gauss Elimination, Pivoting, Matrix factorizations. Iterative Methods: Matrix Norms, Jacobi and Gauss-Siedel Methods, Relaxation Methods. Computation of eigenvalues and eigenvectors: Power method, Householder's method, QR algorithm. Numerical solutions of nonlinear algebraic equations: Bisection, Secant and Newton's method, Zeroes of polynomials, Horner and Muller methods, Equations in higher dimensions.

Ordinary Differential Equations, Initial Value Problems: Euler method, Higher order methods of Runge-Kutta type. Multi-step method, Adams-Bashforth, Adams-Moulton methods, System of ODEs. Ordinary Differential Equations, Boundary Value Problems: Shooting methods, Finite differences, Rayleigh-Ritz methods. Fast Fourier transforms.

TEXTBOOKS/REFERENCES

1. K. E. Atkinson, *An Introduction to Numerical Analysis*, 2nd Edn., John Wiley, 1989.
2. E. K. Blum, *Numerical Analysis and Computation, Theory and Practice*, Addison Wesley Publishing Co., 1972.
3. R.L. Burden and J. D. Faires, *Numerical Analysis*, 7th Edn., Brookes/Cole, 2011.
4. S. D. Conte and C. deBoor, *Elementary Numerical Analysis - an algorithmic approach*, 3rd Edn., McGraw Hill, 1980.
5. J. W. Dummel, *Applied Numerical Linear Algebra*, SIAM 1997.
6. C. F. Gerald and P. O. Wheately, *Applied Numerical Analysis*, 5th Edn., Addison Wesley, 1994.
7. G. H. Golub and C. F. vanLoan, *Matrix Computations*, John Hopkins University Press, 1996.
8. F. B. Hildebrand, *Introduction to Numerical Analysis*, McGraw Hill, New York, 1974.
9. E. Süli and F. D. Mayers, *An introduction to Numerical Analysis*, Cambridge University Press, 2003.
10. L. N. Trefethen and D. Bau, *Numerical Algebra*, SIAM, 1997.
11. D. S. Watkins, *Fundamentals of Matrix Computations*, Wiley, 1991.

MAT 315 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, Möbius 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 approxi-

mations, 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 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. J. Bak and D. J. Newman, *Complex Analysis*, 3rd Edition, UTM, Springer, 2010.
3. J. W. Churchill and R. V. Brown, *Complex Analysis*, Mcgraw-Hill, 2009.
4. T. W. Gamelin, *Complex Analysis*, Springer-Verlag, 2001.
5. R. Greene and S. G. Krantz, *Function Theory of One Complex Variable*, 3rd Edition, GSM, Vol. 40, AMS, 2006.
6. E. M. Stein and R. Shakarchi, *Complex Analysis*, Princeton University Press, 2003.

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

MAT 323 Galois Theory and Commutative Algebra [3003]

PREREQUISITE

1. MAT 312 Abstract Algebra

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

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

TEXTBOOKS/REFERENCES

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

MAT 324 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 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. R. Bhatia, *Notes on Functional Analysis*, Texts and Readings in Mathematics, 2009.
2. J. B. Conway, *A course in Functional Analysis*, Springer, 1997.
3. K. Yoshida, *Functional Analysis*, Springer, 6th ed., 1995.
4. Martin Schechter, *Principles of Functional Analysis*, AMS (Indian Edition, Uni. Press), 2009.
5. Peter D. Lax, *Functional Analysis*, Wiley-InterScience, 2002.
6. M. Reed and B. Simon, *Functional Analysis (Methods of Modern Mathematical Physics - Volume 1)*, Academic Press, 1981.

7. Y. Eidelman, V. Milman and A. Tsolomitis, *Functional Analysis: An Introduction*, GSM, Vol. 66, AMS, 2004.
8. B. Bollabas, *LinearAnalysis*, CambridgeUniversityPress(IndianEdition), 1999.
9. E. Kreyeszig, *Introduction to Functional Analysis with Applications*, Wiley, 1989.
10. W. Rudin, *Functional Analysis*, 2nd Edition, Tata McGraw Hill, 2006.

MAT 412 Analysis on Manifolds [3003]

PREREQUISITES

1. MAT 311 Real Analysis
2. MAT 313 Advanced Linear Algebra

Functions of several Variables: Differentiation, Directional derivatives, Chain rule, Rank theorem, Inverse function theorem and implicit function theorem.

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

Differential forms: Multilinear algebra, tensors, tensor products, alternating tensors, wedge product, tangent spaces, tangent vectors, tangent bundles, differential forms, orientation, Stoke's theorem.

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. S. Shirali and H. L.Vasudeva, *Multivariable Analysis*, Springer 2010.

MAT 413 Partial Differential Equations [3003]

PREREQUISITE

1. MAT 324 Theory of Ordinary Differential Equations

First order partial differential equations: semilinear equations, quasilinear equations, solution of a Cauchy problem; first order nonlinear equations, Charpit's equations, Cauchy problem, the complete integral; Hamilton-Jacobi equations, calculus of variations, Hopf-Lax Formula.

Second order linear partial differential equations: Laplace's equation, fundamental solution, mean value formulas, Green's function, energy methods; Heat equation, fundamental solution, mean value formulas, energy methods; Wave equation, solution by spherical means, non-homogeneous problem, energy methods.

TEXTBOOKS/REFERENCES

1. G. B. Folland, *Introduction to Partial Differential Equations*, 2nd Edition, Princeton University Press, 1995.
2. L. C. Evans, *Partial Differential Equations*, 2nd Edition, American Mathematical Society, 2010.
3. F. John, *Partial Differential Equations*, 4th Edition, Springer, 1981.
4. M. E. Taylor, *Partial Differential Equations I*, 2nd Edition, Springer, 2010.
5. P. Prasad and R. Ravindran, *Partial Differential Equations*, New Age International Publishers, 2005.
6. R. Courant and D. Hilbert, *Methods of Mathematical Physics*, Vol 2: Partial Differential Equations, Interscience Publishers, New York, 1962.

MAT 414 Programming and Data Structures [2023]

Programming fundamentals: variables, data types, operators, expressions, control flow constructs, functions and program structures, I/O operations. Arrays, pointers, memory management, garbage collection. Space and time complexity analysis of algorithms. Structured programming, modular design, top-down and bottom-up approaches. The object oriented paradigm: encapsulation, data abstraction, inheritance, polymorphism.

Array-based implementation of stacks, queues and double-ended queues. Recursion and recursive data structures: linked lists, binary trees, binary search trees and B-Trees. Priority queues and heaps. Graph representation, depth-first search, breadth-first search, shortest path problems. Set manipulation, string manipulation, hash tables, file organization. Comparison of sorting techniques.

TEXTBOOKS/REFERENCES

1. E. Horowitz, S. Sahni and D. Mehta, *Fundamentals of Data Structures in C++*, 2nd Edition, Orient Blackswan, 2008.
2. Mark A. Weiss, *Data Structures and Algorithm Analysis in C++*, 3rd Edition, Addison-Wesley, 2007.

3. A.V. Aho, J.E. Hopcroft and J.D. Ullman, *Data Structures and Algorithms*, Addison-Wesley, 1983.
4. A.M. Tenenbaum, Y. Langsam and M. Augenstein, *Data Structures Using C*, Prentice Hall, 1996.
5. B. Kernighan and D. Ritchie, *The C Programming Language*, Prentice Hall, 1988.
6. Robert Lafore, *Object Oriented Programming in C++*, 4th Edition, Pearson, 2001.

MAT 421 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. K. B. Athreya and S. N. Lahiri, *Measure Theory and Probability Theory*, Hindustan Book Agency, 2006.

2. R. M. Dudley, *Real Analysis and Probability*, Cambridge University Press, 2002.
3. S. R. S. Varadhan, *Probability Theory*, Courant Institute of Mathematical Sciences, 2001.
4. Rick Durrett, *Probability: Theory and Examples*, 4th Edition, Cambridge University Press, 2010.
5. D. W. Stroock, *Probability Theory, An Analytic View*, 2nd Edition, Cambridge University Press, 2010.
6. A. N. Shiryaev, *Probability*, 2nd Edition, Springer, 1995.
7. Jean Jacod and Philip Protter, *Probability Essentials*, 2nd Edition, Springer, 2004.
8. Leo Breiman, *Probability*, Society for Industrial and Applied Mathematics, 1992.
9. P. Billingsley, *Probability and Measure*, 3rd Edition, Wiley (India), 2008.
10. O. Kallenberg, *Foundations of Modern Probability*, 2nd Edition, Springer, 2010.
11. K. R. Parthasarathy, *Introduction to Probability and Measure*, Hindustan Book Agency, 2005.

MAT 422 Differential Geometry [3003]

PREREQUISITE

1. MAT 412 Analysis on Manifolds

Curves: Definition of a curve, Vector field, tangent vector field, unit speed curve, Serret-Frenet formula, Frenet frames; Characterisation of straight lines, circles, Umlaufsatz; Existence of curves with prescribed curvature and torsion.

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.

Curves on smooth surfaces: Gaussian curvature, Gauss-Bonnet theorem, Geodesics.

Manifolds: Definition, examples, Manifolds with boundary, smooth functions, maps between Manifolds; Lie groups, Lie brackets, Lie algebra of a Lie group, covectors and cotangent bundle; Submersion, Immersion and Embeddings.

TEXTBOOKS/REFERENCES

1. M. Spivak, *A Comprehensive Introduction to Differential Geometry*, vol. 1, Publish or perish, 1970.
2. M.P. do Carmo, *Differential Geometry of Curves and Surfaces*, Prentice-Hall, 1976.
3. J.M. Lee, *Introduction to Smooth Manifolds*, Springer 2002.
4. J.M. Lee, *Manifolds and Differential Geometry*, American Mathematical Society, 2009.
5. S. Kumaresan, *A Course in Differential Geometry and Lie Groups*, Hindustan Book Agency, 2002.

Partial List of Electives

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

Physics Syllabus

THEORY COURSES

PHY 111 Mechanics [3103]

Newton's Laws [3]:
Critical analysis of the Newton's laws, Concept of homogeneity and isotropy of space-time, symmetry, Concept of inertial, non inertial reference frames, Fictitious forces, Introduction to Galilean Relativity.

Motion in one dimension [6]:
Analytical solutions of EOMs, Conservation of momentum, Work energy theorem, Use of potential energy graphs to understand motion. Examples: Motion under gravity (rocket motion, block-pully systems); Simple harmonic oscillator and damped oscillator.

Motion in higher dimensions [8]:
Position vector and its derivatives. EOM in Cartesian and Polar Coordinates; Force as the gradient of potential energy; Conservation of angular momentum for a point particle; Examples: Projectile motion, Motion under central force, The Kepler problem.

Rigid bodies [8]:
Centre of mass; Rotational inertia, Momentum and Energy, Conservation laws, Moment of inertia-Examples with simple symmetric bodies. Torque and work energy theorem.

Non-inertial frames [3]:
Rotating reference frames and pseudo-forces;

Special Theory of Relativity [5]:
Measuring space-time in Galilean relativity; Michelson-Morley experiment, Postulates of special relativity, Lorentz transformation-Relativity of Simultaneity, Length contraction, Time dilation; Minkowski space-time diagram, Examples: Twin paradox, Doppler effect.

TEXTBOOKS

1. D. Kleppner and R. Kolenkow, *An introduction to Mechanics*, McGraw-Hill Science/ Engineering/ Math ,1973.

REFERENCES

1. Serway and Jewett, *Physics for Scientists and Engineers*, Brooks/Cole Publishers 2004.
2. C. Knight, W. D. Ruderman, M. A. Helmholz, C. A. Moyer and B. J. Kittel, *Berkeley Physics Course: Vol. I – Mechanics*, McGraw-Hill, 1965.
3. R. Shankar, *Fundamentals of Physics*, Yale Press.

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 [3103]

What is light? [1]:
The corpuscular model and wave model, Particle nature of light and wave nature of matter.

Geometrical Optics [7]:
Fermat's Principle, Laws of reflection and refraction from Fermat's principle, Refraction at a Single Spherical Surface, The thin lens, Thin lens equation, Matrix method in paraxial optics, Thin lens combinations, Aberrations, Prisms, Optical Systems.

Wave Optics [12]:
Wave Motion, One dimensional waves, Harmonic Waves, Phase Velocity, Group Velocity of a wave packet, three-dimensional wave equation, Spherical waves, and cylindrical waves. Polarisation: The nature of polarized light, Polarizers, Malus law, Dichroism, Birefringence, Scattering and Polarization, Polarization by reflection, Brewster angle, Retarders; full-wave plate, half-wave plate, quarter-wave plate, Circular Polarizers, Polarization of Polychromatic light, Maxwell's equation, wave equation, Fresnel reflection coefficient, Total internal reflection, Optical fibre, single mode fibre, multimode fibre, evanescent wave.

Interference [7]:
The superposition principle, phasors and the addition 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 [7]:
Fresnel diffraction: Fresnel Half-period zones, The zone-plate, Diffraction by a straight edge, The Fresnel propagation, Fraunhofer approximation, Fraunhofer diffraction and Fourier optics: Single slit diffraction, Diffraction by a circular aperture, Two-slit Fraunhofer diffraction, N-slit Fraunhofer diffraction, The diffraction grating, Oblique incidence, X-ray diffraction.

TEXTBOOKS

1. Eugune Hecht and A. R. Ganesan, *Optics*, Addison Wesley Longman, 2002.

REFERENCES

1. Ajoy Ghatak, *Optics*, Tata Mgraw-Hill, 2009.
2. 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. [3]

Temperature Scales; Work, Heat and Internal energy, Thermodynamic Processes (reversible, irreversible, quasi-static, adiabatic, isothermal, etc), First law of thermodynamics, Specific heat capacity, Enthalpy, Enthalpy, Joule Thomson experiment. Thermo-chemistry, Hess'Law. [8]

The Second Law of thermodynamics, Gasoline Engine, Carnot cycle and Kelvin temperature scale, Clausius' theorem, entropy and its physical interpretation, entropy change for simple processes. [8]

Thermodynamic functions (Helmholtz free energy, Gibbs free energy, etc), conditions of equilibrium, Maxwell's relations, Chemical potential. [4]

Equilibrium between two phases, general equilibrium conditions, the Clausius-Clapeyron equation, Stability conditions: Le-Chatelier's principle, phase transformation of substances, Third law of thermodynamics. [5]

Fluctuations and equilibrium, irreversibility and approach to equilibrium. Probability concepts-joint probabilities, binomial distribution, mean values, continuous distributions. Concept of ensembles and statistical postulates. Accessible states of an isolated system; association with it's equilibrium parameters and general thermodynamic concepts. [8]

TEXTBOOKS

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

REFERENCES

1. Daniel V. Schroeder, *An introduction to thermal Physics*, Addison- Wesley, 2000.
2. S. J. Blundell and K. M. Blundell, *Concepts in Thermal Physics*, Oxford, 2006.

PHY 311 Mathematical Methods in Physics [3003]

Ordinary differential equations [10]:
Linear equations: Solution space, linear independence, Wronskians. Eigenvalue problems: Boundary conditions, self-adjointness, completeness of Eigen functions, Fourier series, continuous spectra and Fourier integrals. Series solution; Green Functions for ordinary differential operators.

Partial Differential equations [10]:
Preliminaries, important partial differential equations (e.g. heat and wave equations, Poissons and Laplace equations, Helmholtz equation), Solution by separation of variables in cartesian and spherical polar coordinate systems; Greens function for partial differential operators.

Special functions and Applications [2].

Complex Analysis [9]:
Functions of complex variable, limits and continuity, derivatives, analyticity, Cauchy-Riemann conditions, Types of singularities with examples, Contour integrals, Cauchys theorem, Cauchys integral formula, Moreras theorem, Taylor series, Laurent series, Calculus of residues: Residue theorem, Definite real integrals using residue theorem, Cauchys principal value.

Group theory [3]:
Basic concepts: definition, cosets, conjugacy classes, invariant subgroup, factor group, direct product; Representation of groups: definition, unitary representation, reducible and irreducible representation.

TEXTBOOKS/REFERENCES

1. G. B. Arfken and H. J. Weber, *Mathematical methods for physicists*, Academic press.
2. Murray Spiegel, Seymour Lipschutz, John Schiller and Dennis Spellman, *Schaum's Outline of Complex Variables*, 2ed (Schaum's Outline Series).
3. Tulsi Dass and Satish K Sharma, *Mathematical methods in classical and quantum physics*, Universities Press.
4. 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]

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

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

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

Operating principles of FET, MOSFET and Operational amplifiers.

TEXTBOOKS/REFERENCES

1. A. Malvino and D. J. Bates, *Electronic principles*, Mcgraw-hill, 2006.
2. J. Millman, C. C. Halkias and S. Jit, *Electronic devices and circuits*, Tata Macgraw Hill, 2007.
3. S. M. Sze, *Semiconductor Devices, Physics and Technology* (2^{nd} Ed.), Wiley India, 2008.
4. T. L. Floyd and R. P. Jain, *Digital Fundamentals* (8^{th} Ed.), Pearson Education, 2005.

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]

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

Advanced Electronic Materials: Optoelectronic properties and applications.

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

Digital analog and Analog Digital Converters.

Flip-flops, Counters and Shift registers.

TEXTBOOKS/REFERENCES

1. A. Malvino and D. J. Bates, *Electronic principles*, Mcgraw-hill, 2006.
2. J. Millman, C. C. Halkias and S. Jit, *Electronic devices and circuits*, Tata Macgraw Hill, 2007.
3. J. Millman, and C. C. Halkias, *Integrated electronics*, Tata Macgraw Hill, 2008.
4. S. M. Sze, *Semiconductor Devices, Physics and Technology* (2^{nd} Ed.), Wiley India, 2008.
5. T. L. Floyd and R. P. Jain, *Digital Fundamentals* (8^{th} Ed.), Pearson Education, 2005.

PHY 324 Electrodynamics and Special Theory of Relativity [3003]

Special Theory of Relativity [4]:
Principle of Relativity, Lorentz Transformation, Velocity transformation Four vector; velocity and momentum, Notion of Tensors; covariant and contravariant with examples.

Relativistic Mechanics [4]:
Principle of least action, Energy and momentum, Transformation of distribution functions, Elastic collisions, Angular momentum.

Charges in electromagnetic fields [6]:
Elementary particles in special theory of relativity, Four potential of a field, Gauge invariance, Electromagnetic field tensor, Lorentz transformation of the electromagnetic field, Invariants of the field.

Electromagnetic field equations [6]:
The action for the electromagnetic field and the first pair of Maxwell's equations, Four dimensional current vector, Continuity equation; The second pair of Maxwell's equations, Energy density and energy flux, The energy-momentum tensor of the electromagnetic field.

Constant electromagnetic fields [3]:

Coulomb's 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. Larmor's theorem.

Electromagnetic waves [4]:
The wave equation, Plane waves; Poynting Vector and Energy Carried by the plane wave. Polarisation.

Electromagnetic field of moving charges [3]:
Retarded and advanced potentials. Lienard-Wiechert potentials.

Radiation of Electromagnetic fields [6]:
Dipole radiation; Quadropole and magnetic dipole radiation; radiation from rapidly moving charge; near and far field solutions and properties of radiation.

TEXTBOOKS

1. L. D. Landau and E. M. Lifshitz, *Classical Theory of Fields*, Vol-2 of course of theoretical physics, Pergamon, 2000.
2. J. D. Jackson, *Classical Electrodynamics*, 3rd Ed., John Wiley, 1999.

REFERENCES

1. David J. Griffiths, *Introduction to Electrodynamics*, Prentice Hall, 1999.
2. Frank S. Crawford Jr., *Waves*, Berkeley Physics Vol 3.
3. A. P. French, *Special Theory of Relativity*.
4. Bernard F. Schutz, *A first course in General Relativity*, Cambridge, 2009.

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. Simple pendulum & variable g pendulum
2. Conservation of energy
3. Conservation of momentum & ballistic pendulum
4. Centripetal force
5. Symmetric compound bar pendulum
6. Projectile motion
7. Melde's string
8. Sonometer
9. Newton's laws of Motion
10. Moment bar

PHY 122 Experiments in electrodynamics [0031]

1. Potentiometer-internal resistance of a cell
2. Magnetic field along the axis of a circular coil
3. Conversion of galvanometer to voltmeter
4. Deflection magnetometer
5. Zener regulator
6. Characteristics of pn junction diode and verification of truth tables for 'and' and 'or' gates
7. Full wave rectifier with and without filters
8. Electronic circuit using computer interface
9. Ballistic galvanometer absolute capacity of a capacitor
10. Spot galvanometer- high resistance by leakage

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. Liquid lens
8. Reflection grating
9. Malu's law
10. Spectrometer- (i-d curve)

PHY 222 Experiments on Heat and Thermodynamics [0031]

1. Newton's law of cooling
2. Specific latent of steam
3. Thermal conductivity of rubber
4. Specific heat capacity of solid-method of mixtures
5. Joule's calorimeter-specific heat capacity of liquid
6. Thermal conductivity-Lee's disc
7. Potentiometer-thermo e m f
8. Stefan's constant
9. Latent heat of fusion of ice
10. P V Diagram

PHY 315 Advanced Physics Experiments I [0093]

1. Viscosity of a liquid - Oscillating disc method
2. Young's modulus: Cornu's method
3. Spectrometer- $i - i'$ curve
4. Spectrometer- Hartmann's constant
5. Young's modulus- Optic lever method
6. Surface tension- Capillary method
7. Beam profile of laser
8. Diffraction by ultrasonic waves- velocity of sound in liquid
9. e/m - Thomson's method
10. Fabry-Perot interferometer

11. Michelson's interferometer
12. LCR circuit (series and parallel)- Frequency response and the value of unknown L
13. Transistor characteristics and transistor as an amplifier
14. Phase shift oscillators

PHY 325 Advanced Physics Experiments II [0093]

1. Velocity of light- Foucoult's method
2. Photoelectric effect
3. Arc Spectrum- Iron or Brass
4. X-ray diffractometer
5. FET characteristics and amplifier using FET
6. Op-Amp: Frequency response and mathematical tools
7. Op-Amp: Square, triangular and saw-tooth wave generator
8. Band pass and band reject filters
9. Differential amplifier using transistor
10. Amplitude modulation
11. Digital electronics using trainer kit-Binary to decimal, decimal to binary and D/A converter
12. Schmitt trigger
13. Chaotic Oscillator
14. Scanning Tunnelling Microscope - Topography

PHY 415 Advanced Physics Experiments III [0093]

1. Zeeman effect
2. Hall effect
3. Electron spin resonance spectrometer
4. Electrical resistivity of semiconductor and noble metal resistor
5. Magnetic susceptibility - Quincke's Method
6. $B - H$ Curve
7. Two slit Interference - one photon at a time
8. GM counter and gamma ray spectrometer
9. Optical fiber communication
10. Thin film deposition and characterization
11. Atomic Force Microscope

Interdisciplinary Courses

IDC 111 Mathematical Tools I [2023]

Matrices:
Revision of Matrices, 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.

Matlab/Octave/Python Hands-ON Exercises: [4 weeks]
Introduction to MATLAB/Octave/Python. Data handling. Basic Plotting 2D and 3D. 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. Diagonalisation and Eigenvalue 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 homogeneous equations with constant coefficients, Linear Independence of solutions-Wronskian, Non-homogeneous equations general solution. System of Linear ODEs.

Matlab/Octave/Python Hand-ON Exercises: [6 weeks]
Numerical differentiation. Euler's method to solve ODEs. First ODE Examples: Free particle under gravity, Evolution of chemical concentration in a reaction, Motion in viscous media/magnetic field Second ODE Examples: Harmonic oscillator with/without damping. First order coupled ODE: Predator-Prey problem. Solution of a system of linear ODE.

TEXTBOOKS

1. E. Kreyszig, *Advanced Engineering Mathematics*, 8th Edition Wiley India Pvt Ltd, 2006.
2. Richard Bronson, Gabriel Costa, *Schaum's Outlines Differential Equations*, 3rd Edition Mcgraw-hill 2009.

3. C. Edwards and D. Penny, *Elementary Differential Equations with Boundary Value Problems*, 5th Edition Prentice Hall 2007.

IDC 121 Mathematical Tools II [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.

Mathematica Exercises: [4 weeks]
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.

Mathematica Exercises: [4 weeks]
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, divergence and curl.

Fourier Series:
Fourier expansion of a periodic functions.

Mathematica Exercise: [1 week]
Demonstration of Fourier series representation for simple waveforms (e.g. Square, triangular, saw tooth).

Complex numbers and functions:
Arithmetic operation, conjugates, modulus, polar form, powers and roots; Derivative;

Mathematica Exercise: [1 week]
Algebraic Manipulation of complex functions.

TEXTBOOKS

1. E. Kreyszig, *Advanced Engineering Mathematics*, 8th Edition Wiley India Pvt Ltd, 2006.
2. Murray R. Spiegel, *Schaum's Outlines Vector Analysis*, Tata Mcgraw Hill 2009.
3. Murray R. Spiegel, *Schaum's Outlines Fourier Analysis with Applications to Boundary Value Problems*, Tata Mcgraw Hill 2006.
4. Murray R. Spiegel, Seymour Lipschutz, John Schiller, Dennis Spellman, *Schaum's Outlines Complex Variables*.
5. Stephen Wolfram, *The MATHEMATICA Book*, 5th Edition.

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; Vibrational 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*.

Humanities Syllabus

Institute will offer some of the humanities courses from the list below from time to time.

Introduction to Psychology

Psychological Science- Assumptions, schools, methods of doing psychology research, The relationship between brain, body and mental functioning, Sensation, perception and making sense of the world, Consciousness, Life span development and motor and language development, Nature and nurture controversy, The learning process and some important explanations of how we learn, Meaning of motivation and explanations, Theories of emotions and expression and regulation of emotions, Basic cognitive processes, Language development, why we remember and why we forget- some explanations, Different kinds of intelligence, explanations of creativity, Differences among individuals and explanations for personality differences, Application of psychology to everyday life- enhancing health and well-being, performance, social relations, and sensitivity to environmental, social and cultural contexts.

Theories of Personality

Personality: Meaning & Assessment. Psychoanalytic & Neo-Psychoanalytic Approach ; Behavioural Approach; Cognitive Approach; Social- Cognitive Approach; Humanistic Approach; The Traits Approach; Models of healthy personality: the notion of the mature person, the self-actualizing personality etc. Personality disorders; Psychotherapeutic techniques and Yoga & Meditation; Indian perspective on personality; Personality in Socio-cultural context.

Environment, Development and Society

Students will be exposed to contemporary themes and debates on connection between environment, development, and society; industrialization and risk society; challenge of sustainable development; perception of the environment, dependence for livelihood, identity, and power on natural resources; social ecology; what is the role of religion in determining our world view and relation with the environment?; recognition of indigenous knowledge; rise of environmental movements, development projects and recent conflict over natural resources; understanding major environmental disasters and industrial accidents; global climate change negotiations; gender and environment.

Introduction to Sociology

The course will introduce students to the study of sociology and some basic underpinnings of sociological theory and methodology. The emergence of sociology as a scientific discipline is examined in the context of the development of Industrial society in Western Europe. The course will examine the writings of key classical social thinkers such as Marx, Durkheim and Weber as well as more contemporary theorists such as Michel Foucault, with a view to understanding various sociological approaches to modern industrial society

Science, Technology and Society

The course will begin with social theories on the production of technology and scientific knowledge systems, stratification within the community of technologists and scientists, discrimination (race, class, gender, caste) and the role of power in shaping the production of technology and scientific knowledge. Scientific controversies, both historical and emerging, and the organization of innovation and its geographies will be discussed. Case studies exploring ethical questions arising from new technologies such as information technology, nanotechnologies, biotechnologies, etc. will be used. Discussions on public understanding of science and role of the public and of experts in influencing policies related to science and technology will conclude the course.

Introduction to Logic

In this course, students are introduced to fundamentals of informal logic and verbal analysis, material and formal fallacies of reasoning often found ordinary discourse, deductive and Inductive reasoning, validity and soundness, formal rules and principles of the deductive system of Aristotelian logic, traditional square of opposition; propositional calculus; first order predicate calculus; the modern square of opposition and the problem of existential import; identity and definite descriptions; methods for formulating natural language arguments in symbolic forms and techniques for checking their validity; various meta-logical theorems and their proofs.

Introduction to Philosophy

What makes philosophical thinking radically critical? Investigation of the nature of knowledge about the world and justification of knowledge claims. Metaphysical understanding of the Absolute and Mind-Body relation. The nature of ethical and aesthetic beliefs and attitudes as part of understanding the nature of values. The discussion of the above issues will be influenced by three philosophical orientational perspectives: Anglo-American Analytic, Continental Phenomenological and Classical Indian.

Philosophy of Mind

An appreciation of how the fundamental mental concepts are essentially amenable to philosophical sense over and above their usual psychological understanding and analysis. To explain why our mental conceptual scheme does not easily admit of their reduction to physical conceptual scheme. To reflect on whether mentally endowed human person differ, ontologically, from the rest of nature

Philosophy of Science

Science is regarded as the most significant cognitive enterprise of the modern society. In view of this, the course addresses the question what sets science apart from other epistemic activities. Further It concentrates on debates on the nature of scientific methods, logical reconstruction of

scientific explanation, the relation between theories and laws on the one hand, and empirical evidence on the other, the nature of the justification and the notion of truth involved in scientific knowledge, and the societal influence on scientific practice.

Communication Skills (Advanced Level)

Introduction to major grammatical models. Phonological and syntactical structure of present- day English. Language of science and technology. Aspects of style. Some common errors. Technical presentations design and delivery. Audio Visuals in communication. Collecting materials for research. Organization of research paper/dissertation

Introduction to Economics

What is Economics? Scarcity, choice and economic systems; Supply and demand; elasticity of demand; Comparative advantage and international trade; Consumer choice; Consumer theory with indifference curves; Production and cost; How firms make decisions: profit maximization; Perfect competition;Monopoly and imperfect competition; Economic efficiency and the role of government;Labor markets and wages; Introduction to macroeconomics; Production, income and employment; The monetary system, prices and inflation; Economic growth & rising living standards;Economic Fluctuations; The banking system, the Fed & monetary policy; Aggregate demand and aggregate supply

Planning and Economic Development (Advanced Level)

Economic growth. Economic development. Historic growth and contemporary development. Lessons and controversies. Characteristics of developing countries. Obstacles to development. Structural changes in the process of economic development. Relationship between agriculture and industry. Strategies of economic development. Balanced/ Unbalanced growth. International trade and economic development. Population. Planning for economic development. Use of input-output model and linear programming techniques in planning. Indian plan experience. Strategy of Indian planning. Indian plan models.

International Economics

Basic concepts of national income accounting, money, and balance of payments; output and exchange-rate determination under fixed and flexible exchange-rate regimes; fiscal and monetary policies in an open economy; international capital movements and their impacts; Case Studies: East Asian crisis, global financial crisis; theories of international trade including factor-proportions and economies of scale; the international trading regime and its implications for developing countries.

Industrial Economics

Basic concepts: Plants, firm and industry. Market structure. Economics of scale and optimum firm size. Pricing under alternative market structures. Market power and concentration. Integration, diversification and merger. Behavioural and managerial theories of the firm, growth of the firm. Industrial productivity and its measurement. Industrial location. Input- output analysis. Project appraisal and capital budgeting. Industrialisation and economic development. Problems of industrialisation in India. Role of public and private sectors. Growth of small-scale industries and their problems. Government regulation of industry. Balanced regional development.

Applied Game Theory

This module introduces students in economics and other social sciences to game theory, a theory of interactive decision making. This module provides students with the basic solution concepts for different types of non-cooperative games, including static and dynamic games under complete and incomplete information. The basic solution concepts that this module covers are Nash equilibrium, subgame perfect equilibrium, Bayesian equilibrium, and perfect Bayesian equilibrium. This module emphasizes the applications of game theory to economics, such as duopolies, bargaining, and auctions.

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