INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH THIRUVANANTHAPURAM

An autonomous institution under the

Ministry of Human Resource Development, Government of India

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

2012-13

www.iisertvm.ac.in

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

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

IISER THIRUVANANTHAPURAM CAMPUS

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

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

Registration

- Every student must register for the courses of a semester on the first day (registration day) of the semester.
- Registration involves payment of the prescribed fees for the semester.
- A fine of Rs.100/- per day will be levied for late registration done after the first day of class.

- Late registration after the first week of the semester can only be done with the permission of the Dean (Academics) or the Director of the institute.

Faculty Adviser

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

Assessment and Grading

CONTINUOUS ASSESSMENT

Continuous assessment will be adopted for all courses.

Theory Course :

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

Practical Course :

Class experiments	: 70%
End Semester Examination	: 30 %

GRADING

Relative grading will be adopted.

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

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

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

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

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

(d) Cumulative Grade Point Average is calculated as

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

Where, C_k = Credit for k^{th} course; G_k =Grade point secured by the student. Summation is over all the courses credited by the student in *all the completed semesters*.

Requirements for the award of the BS-MS dual degree

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

Essentials for completing courses

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

Removal from the rolls

- Failure to maintain the minimum CGPA of 4.0 in any two consecutive semesters will lead to automatic removal of the student from the rolls.

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

Project Evaluation

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

the Project Evaluation Committee and the result will be submitted to the Project Coordinator, who in turn will forward it to the Academic Section.

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

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

Sample transcript

Indian Institute of Science Education and Research, Thiruvananthapuram

GRADE TRANSCRIPT

Five Year Integrated Masters Degree in Science

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

Grades for Varsha xxx*

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

Semester Grade Point Average: **6.63**

Cumulative Grade Point Average: **6.63**

Date:

Thiruvananthapuram

Dean, Academics

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* *Varsha Semester: August – December, Vasanth Semester: January – May*

Grade Points: $A^+ = 10, A = 9, B^+ = 8, B = 7, C^+ = 6, C = 5, D = 4, F = 0,$

I=Incomplete, M=Medical Leave

Conduct Regulations

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

   IISER TVM STUDENT HONOUR PLEDGE

   a. I promise, on my honour, that I will conduct myself in the Institute and outside, with decorum and decency befitting the high moral and ethical standards expected of the members of the National Institute, IISER TVM and follow its rules and regulations
   b. I will not engage in ragging. I understand that ragging is unlawful and liable to prosecution by law enforcement authorities of the State besides any disciplinary action the Institute may take which may include dismissal from the Institute.
   c. I will not engage in overt/covert sexual harassment.
   d. I will not resort to any dishonest practice in examinations/assignments.
   e. I will not engage in plagiarism in my writings and will acknowledge the work of other authors according to international 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 sign, at the time of admission, the prescribed anti-ragging forms (see: www.iisertvm.ac.in) as per the stipulation of the MHRD, Govt. of India.

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

Library Regulations

1. Library hours:

   1. Library remains open from 9 AM to 7.30 PM on Monday to Friday.

   2. During Exam Week : 9 AM to 10 PM
   3. Circulation of Books will be between 9.15 AM to 5.15 PM on Monday to Friday.
   4. On Saturdays Circulation of Books will be till 12 noon; however, library remains open till 5 PM.
   5. Sundays and Holidays: Closed

2. Membership: All BS-MS students are eligible for membership at the institute library
3. Borrowing facility: BS-MS students can borrow a maximum of 4 books at a time for 2 weeks, provided they do not have any overdue book with them.
4. Users must leave their Bags and other belongings outside the Library. Only notebooks and papers are allowed inside the library. Issued books are allowed to be taken to the Library for return/renewal only. All items taken out of the library are to be produced for verification by the check point staff engaged in front of the Library.
5. Always carry the Identity card and must be produced whenever asked for.
6. Silence has to be maintained by all users in the Library.
7. Use of Mobile Phones, consumption of food and drinks are strictly prohibited in the Library.
8. Return of book is mandatory before the due date. A fine of Re.1/- per day per book for the first week of delayed return and Rs.10/- per day per book thereafter will be levied. Renewal of a book is possible only if there is no pending reservation against it. A book may be recalled anytime before the due date if it is urgently required by another member. A late fee of Rs. 10/- per day per book will be imposed for the non-compliance with the requirement.
9. Mutilation of books in any form (e.g. underlining, writing on pages, tearing off pages, damaging the binding etc) will lead to a heavy fine or even replacement of the book. Before borrowing a book users should look at the condition of the book and bring to the notice of the library staff if any mutilation found.
10. Members who lose/mutilate library materials are liable to replace the book with latest edition of the books along with a penalty of 20% of the total cost of the book. All books replaced in this manner must be of the latest edition. If the book is part of a set or series they may be

called upon to replace the whole set or series. In case of the lost books is untraceable in market or out of print Library committee reserves the right to decide appropriate penalty.

11. BS-MS students should return all the books they have borrowed before they go for vacation
12. Users should obey the Library Rules and Regulations. Violation of rules and any act of misbehaviour to the library staff will be brought to the notice of the Library Committee Chair, and will lead to strong disciplinary action.

Hostel Regulations

1. Please do not make noise in the rooms, corridors and premises of the hostel especially during night.
2. Keep your rooms and premises clean and tidy. You are responsible for keeping your rooms clean.
3. Please take utmost care not to damage furniture, TV, washing machines, building structure, electrical fittings etc.
4. Strictly avoid getting into arguments with fellow hostellites, localites and office staff.
5. Cooking inside the rooms is strictly prohibited.
6. Guests are not allowed in hostel rooms.
7. In case of any emergency (illness, accidents etc), contact the concerned warden.
8. Any overt or covert sexual/caste/religion/creed/linguistic/color remark will lead to immediate removal of the offender from the institute rolls.
9. All students must return to the hostel by 10.00 pm.
10. Bringing illegal substances such as explosives, drugs, narcotics and other illegal substances to the hostel /hostel premises is strictly prohibited.
11. Please switch off all electrical equipment after usage, if found otherwise, a fine will be levied, including recovery of cost of electrical equipment/fitting/ appliances etc.
12. Please take care of your personal belongings.
13. Anti-ragging regulations of the institute have to be strictly followed in the hostels too.

14. Leaving the hostel for a day or longer need prior permission from the concerned warden.
15. Use of drugs/alcoholic beverages/tobacco products in the hostels is strictly prohibited. Smoking in public is a punishable offence.
16. Students should be either in the hostel or in the IISER. Prior permission from the concerned warden has to be obtained in case the student need to go anywhere else. This has also to be recorded in the register kept for the purpose in the Hostel.
17. Permanent address including the phone numbers of the parent/guardian has to be given to the Warden/IISER office. Also the address has to be updated whenever there is a change due to shifting/ change of phone number of the parent etc.
18. All the BS-MS students have to vacate the hostel during the vacation time. If any student has to stay back during the vaccation, special permission has to be obtained from the competent authority in advance.

INSPIRE/KVPY Fellowship

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

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

MOODLE and Course Feedback

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

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

Course Structure

The first two years of the BS-MS programme consists of CORE or 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 CORE courses are numbered in the format,

XYZ YSC (LTPC)

The ELECTIVE courses are numbered in the format,

XYZ YSCC (LTPC)

The numbering may be understood as

XYZ	:	Subject Code
Y	:	Year
S	:	Semester Number
C (CC)	:	Number of the course (in a particular subject) in that year
L	:	Lecture hours
T	:	Tutorial hours
P	:	Practical hours
C	:	Credits

Subject codes

BIO :	Biology
CHY :	Chemistry
MAT :	Mathematics
PHY :	Physics

First four semesters

FOUNDATION COURSES FOR 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	Biochemistry	3	1	0	3
CHY 111	Atomic Structure & Chemical Bonding	3	1	0	3	CHY 121	Chemistry of Elements	3	1	0	3
MAT 111	Introduction to Algebra	3	1	0	3	MAT 121	Introductory Analysis-I	3	1	0	3
PHY 111	Mechanics	3	1	0	3	PHY 121	Electromagnetism	3	1	0	3
IDC 111	Mathematical Tools-I	2	0	2	3	IDC 121	Mathematical Tools-II	2	0	2	3
HUM 111	Communication Skills	0	1	0	1	HUM 121	Humanities	0	1	0	1
BIO 112	Introductory Biology Lab	0	0	3	1	BIO 122	Biochemistry 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	Genetics & Mol. Biology	3	1	0	3	BIO 221	Ecology and Evolution	3	1	0	3
CHY 211	Chemical Reactions & Reactive Intermediates	3	1	0	3	CHY 221	Principles of Physical Chemistry	3	1	0	3
MAT 211	Introductory Analysis-II	3	1	0	3	MAT 221	Introduction to Statistics	3	1	0	3
PHY 211	Optics	3	1	0	3	PHY 221	Thermal &Statistical Physics	3	1	0	3
IDC 211	Principles & Appl. of Spectroscopy	3	1	0	3	IDC 221		3	1	0	3
HUM 211	Humanities	0	1	0	1	HUM 221	Humanities	0	1	0	1
BIO 212	Genetics & Molecular Biology Lab	0	0	3	1	BIO 222	Ecology 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: 76											

Semesters 5 to 10

Major and Minor Courses

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

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

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

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

In addition to the courses, each student will undertake a one year research project in his/her major subject worth 24 credits during the 5^{th} year. The 6 credit mini project undertaken by the student during the 8^{th} semester should be done in a school other than the school of his/her major.

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 courses that carry more credits than what is shown. The number of courses, however, shall remain fixed for each semester.

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

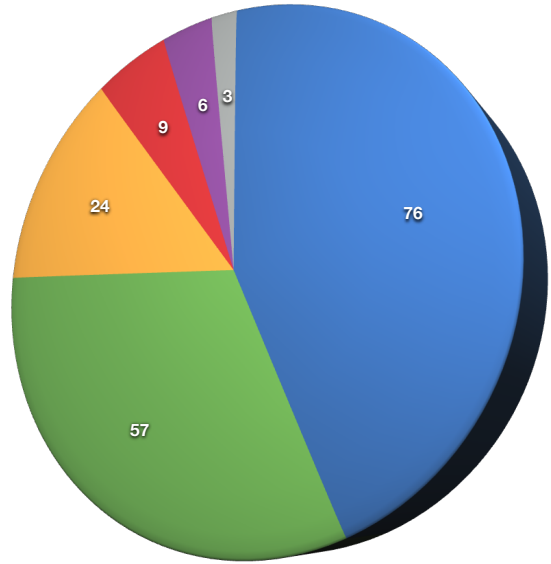
SEMESTER 9

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



First and Second Year
Courses in major (Theory/Lab)
One year project in major
Courses in minor (Theory)
Mini project in minor
Humanities

Biology Major

MAJOR IN BIOLOGY (THIRD YEAR TO FIFTH YEAR)

Semester –V						Semester -VI					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 311	Microbiology	3	0	0	3	BIO 321	Bacterial Genetics	3	0	0	3
BIO 312	Immunology	3	0	0	3	BIO 322	Biophysics & Structural Biology	3	0	0	3
BIO 313	Advanced Cell Biology	3	0	0	3	BIO 323	Advanced Biochemistry	3	0	0	3
BIO 314	Evolutionary Ecology	3	0	0	3	BIO 324	Neurobiology	3	0	0	3
BIO 315	Advanced Biology Lab-I	0	0	9	3	BIO 325	Advanced Biology Lab-II	0	0	9	3
Total		**12**	**0**	**9**	**15**	**Total**		**12**	**0**	**9**	**15**
Cumulative Credits at the End of Third Year: 106											
Semester –VII						**Semester -VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 411	Developmental Biology	3	0	0	3	BIO 421	Mathematical & Systems Biology	3	0	0	3
BIO 412	Biostatistics	3	0	0	3	BIO 422	Advanced Genetics	3	0	0	3
BIO 413	Advances in Plant Biology	3	0	0	3	BIO 423	Advanced Molecular Biology	3	0	0	3
BIO 414	Genomics	3	0	0	3	BIO 4201	Elective -I	3	0	0	3
BIO 415	Advanced Biology Lab-III	0	0	9	3						
Total		**12**	**0**	**0**	**15**	**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 133											
Semester –IX						**Semester -X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 511	Major Project	9	0	0	9	BIO 521	Major Project	15	0	0	15
BIO 5101	Elective-II	3	0	0	3						
Total		**12**	**0**	**0**	**12**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 160											

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

Chemistry Major

MAJOR IN CHEMISTRY (THIRD YEAR TO FIFTH YEAR)

Semester –V						Semester -VI					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
CHY 311	Advanced Coordination Chemistry	3	0	0	3	CHY 321	Organometallics Chemistry	3	0	0	3
CHY 312	Quantum Chemistry	3	0	0	3	CHY 322	Advanced Molecular Spectroscopy	3	0	0	3
CHY 313	Stereochemistry-Principles & Applications	3	0	0	3	CHY 323	Advanced Organic Chemistry-I	3	0	0	3
CHY 314	Instrumental Methods	3	0	0	3	CHY 324	Spectroscopic Methods in Structure Determination	3	0	0	3
CHY 315	Advanced Organic Chemistry Lab	0	0	9	3	CHY 325	Advanced Inorganic Chemistry Lab	0	0	9	3
Total		**12**	**0**	**9**	**15**	**Total**		**12**	**0**	**9**	**15**
Cumulative Credits at the End of Third Year: 107											
Semester –VII						**Semester -VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
CHY 411	Chemistry of Solids & Materials	3	0	0	3	CHY 421	Electrochemistry	3	0	0	3
CHY 412	Advanced Chemical Kinetics	3	0	0	3	CHY 422	Physical Organic Chemistry	3	0	0	3
CHY 413	Advanced Organic Chemistry-II	3	0	0	3	CHY 423	Advanced Organic Chemistry-III	3	0	0	3
CHY 414	Bioinorganic Chemistry	3	0	0	3	CHY 4201	Elective	3	0	0	3
CHY 415	Advanced Physical Chemistry Lab	0	0	9	3						
Total		**12**	**0**	**9**	**15**	**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 134											
Semester –IX						**Semester -X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
CHY 511	Major Project	9	0	0	9	CHY 521	Major Project	15	0	0	15
CHY 5101	Elective	3	0	0	3						
Total		**12**	**0**	**0**	**12**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 161											

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

Mathematics Major

MAJOR IN MATHEMATICS (THIRD YEAR TO FIFTH YEAR)

Semester –V						Semester -VI					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
MAT 311	Real Analysis	3	0	0	3	MAT 321	Complex Analysis	3	0	0	3
MAT 312	Discrete Mathematics	3	0	0	3	MAT 322	Measure Theory and Integration	3	0	0	3
MAT 313	Abstract Algebra	3	0	0	3	MAT 323	Galois Theory & Commutative Algebra	3	0	0	3
MAT 314	Advanced Linear Algebra	3	0	0	3	MAT 324	Multivariate Analysis	3	0	0	3
MAT 315	Numerical Analysis	3	0	0	3	MAT 325	General Topology	3	0	0	3
MAT 3101*	Elective I- Operation Research	3	0	0	3						
Total		**18**	**0**	**0**	**18**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Third Year: 109											
Semester –VII						**Semester -VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
MAT 411	Functional Analysis	3	0	0	3	MAT 421	Advanced Analysis	3	0	0	3
MAT 412	Probability Theory & Random Processes	3	0	0	3	MAT 422	Partial Differential Equations	3	0	0	3
MAT 413	Number Theory and Cryptography	3	0	0	3	MAT 423	Combinatorics & Graph Theory	3	0	0	3
MAT 414	Theory of Ordinary Differential Equations	3	0	0	3	MAT 424	Differential Geometry	3	0	0	3
MAT 415	Reading Seminar	0	0	3	1	MAT 4201	Elective-III	3	0	0	3
MAT 4101*	Elective II- Programming & Data Structures	3	0	2	4						
Total		**15**	**0**	**5**	**17**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fourth Year: 141											
Semester –IX						**Semester -X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
MAT 511	Major Project	9	0	0	9	MAT 521	Major Project	15	0	0	15
MAT 5101	Elective-IV	3	0	0	3						
MAT 5102	Elective-V	3	0	0	3						
Total		**15**	**0**	**0**	**15**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 171											

Remark 1:- *The school is not obliged to offer an elective in a particular semester if situation warrants.*

Remark 2: *To meet the minimum requirement of 175 credits for qualifying the BS-MS Degree, students may take minor or additional courses.*

Remark 3: *The electives MAT 3101/ MAT 4101 will be offered in every alternate year*

Physics Major

MAJOR IN PHYSICS (THIRD YEAR TO FIFTH YEAR)

Semester –V						Semester –VI					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
PHY 311	Mathematical Methods	3	0	0	3	PHY 321	Statistical Mechanics	3	0	0	3
PHY 312	Classical Mechanics	3	0	0	3	PHY 322	Condensed Matter-I	3	0	0	3
PHY 313	Electronics-I	3	0	0	3	PHY 323	Electronics-II	3	0	0	3
PHY 314	Quantum Mechanics-I	3	0	0	3	PHY 324	Electrodynamics & Special Theory of Relativity	3	0	0	3
PHY 315	Advanced Physics Experiments Lab-I	0	0	9	3	PHY 325	Advanced Physics Experiments Lab-II	0	0	9	3
Total		**12**	**0**	**9**	**15**	**Total**		**12**	**0**	**9**	**15**
Cumulative Credits at the End of Third Year: 106											
Semester –VII						**Semester –VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
PHY 411	Experimental Methods	3	0	0	3	PHY 421	High Energy Physics	3	0	0	3
PHY 412	Condensed Matter-II	3	0	0	3	PHY 422	Atomics & Molecular Physics	3	0	0	3
PHY 413	Quantum Mechanics-II	3	0	0	3	PHY 423	Computational Techniques & Programming Language	3	0	0	3
PHY 414	Elective-I	3	0	0	3	PHY 4201	Elective-II	3	0	0	3
PHY 415	Advanced Physics Experiments Lab-III	0	0	9	3	PHY 4202	Elective-III	3	0	0	3
PHY 416	Workshop & Engineering Drawing	0	0	3	1						
Total		**12**	**0**	**12**	**16**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fourth Year: 137											
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-IV	3	0	0	3						
Total		**12**	**0**	**0**	**12**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 164											

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 forms is to be filled up and submitted to the Dean Academics. The choice of major and minor courses will be finalized in a counseling session involving students and concerned members of the faculty.

INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH THIRUVANANTHAPURAM

Academic Section

Application form for choosing Major

1 Name: _____

2 Roll No: _____

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

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

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

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

2 _____

Declaration:

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

Date : (Signature of the Student)

Biology Syllabus

THEORY COURSES

BIO 111 Introductory Biology [3103]

Science of Biology:- The stuff of life (Biological Macromolecules) Nucleic Acids, Proteins, Lipids, Carbohydrates Concept of gene; transcription, translation.

Construction Plans for Cells and Organisms Sizing up *E. coli* Cells & Structures within them:- variety of shapes and functions (human cell variation); Cellular interior: organelles; Macromolecular assemblies including viruses; From pdb to visualization.

Multicellularity:- Biofilms and *Dictyostelium*, communities of cells Tissues to neuronal networks, Multicellular organisms - *C. elegans*; colonies of organisms.

Time Scales in Biology:- Cell Cycle to evolutionary time scales; 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, Membrane Proteins and Transmembrane Transport.

Model Systems:- Haemoglobin as a Model Protein; Ligand binding and Ligand-Receptor Interactions, Oxygen Binding Equilibria (excursion to high altitudes and cold climates), Haemoglobin and origins of Structural Biology, Molecular Models of Disease, Bacteriophage & Molecular Biology: Delbruck-Luria and fluctuation test, Hershey-Chase, Seymour and collinearity of DNA and protein, Brenner-Crick and triplet codon, *E. coli*: experiments on conservative replication, lacoperon and genetic circuits, bacterial chemotaxis, yeast: rise of biochemistry, cell cycle, membrane traffic, Flies: Drosophila and Modern Genetics, How the fly got its stripes, Mice, *Arabidopsis* & Humans; Exotica: Squid Axon, *C. elegans*.

Hierarchical levels of organization in Biology:- Variation and Diversity of life: Viruses, bacteria protists, fungi, Plant and animal kingdoms.

TEXTBOOKS/REFERENCES

1. Rob Phillips, Jane Kondev, Julie Theriot., *Physical Biology of the Cell*, Garland Science
2. Campbell and Reece, *Biology*, 7^{th} edition, Pearson-Benjamin Cummins
3. Raven, Johnson, Losos, Mason, and Singer, *Biology*, 8^{th} Edition, Mcgraw Hill

BIO 121 Biochemistry [3103]

Central Dogma & The Molecules:-Central Dogma; Nucleotides; DNA double helix; Amino Acids and Proteins,Side chain classification, Protein structure, Hydrophobic core, Secondary Structure; Replication; Transcription; Triplet Code; Translation; Reverse transcriptase.

Nucleic Acids:- Double Helical Structures of DNA and RNA, Sugar pucker and orientation, RNA and A-form, B-DNA, Z-DNA, The grooves, Supercoiling, Non-standard bases and base pairing in RNA.

Carbohydrates:- Linear and cyclic forms of monosaccharides, Sugar ring conformations, Modified sugars, Oligo- and Polysaccharides, Glycoproteins and glycolipids, Sugars and cell-cell recognition.

Lipids & Membranes:- Lipid structures, Micelles, planar bilayers, vesicles, Lipid-protein, Lipid Domains, Cell membranes and compartments.

Proteins:- Hierarchical organization (primary, secondary, tertiary, quarternary), 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,Membrane Proteins, Membrane Transport, Thermodynamic Hypothesis Protein Folding, Protein Sequence Comparison Structural Variation, Modular Domains.

Biochemical Thermodynamics:- Enthalpy, Entropy, Free Energy, Chemical Potential, Redox; Enzymes:-Michaelis-Menten kinetics, Allosteric Enzymes, Enzyme Catalysis Mechanisms, Example of protease.

TEXTBOOKS/REFERENCES

1. J. Kurien, *The molecules of life* (in press).
2. Berg, Tymoczko and Stryer, *Biochemistry*, W. H. Freeman and Company,

BIO 211 Genetics and Molecular Biology [3103]

Introduction to genetics and key words

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, introduction toepigenetics, infection heredity.

Genetics interactions: approach towards generating a network (Epistasis, redundancy, synthetic leathality, lethal interactions)

Tools to study genetics: forward genetics (map based cloning), reverse genetics (RNA interference), expression pattern in time and space.

Studies on molecular genetic interactions.

Genome composition: Organization of the genome, Coding and noncoding sequences, Regulatory elements, repeat sequences, transposons, organelle genomes.

Chromosome structure and function: Packaging of DNA into the nucleus, nucleosomes, chromosome features-centromeres, telomeres, 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.

DNA Recombination: Recombination models, Recombination proteins, Gene conversion,Homologous Recombination, DNA recombination and chromosome segregation.

TEXTBOOKS/REFERENCES

1. Benjamin Lewis, *Genes IX*, Jones and Bartlett 2007.
2. Watson et al., *Molecular Biology of the Gene*, Benjamin-Cummins 2008.
3. Friedberg, *DNA Repair and Mutagenesis*, Plenum Publishers 1987.

BIO 221 Ecology and Evolution [3103]

Overview: The science of ecology and evolution, why study ecology and evolution?
Distribution of living things: The role of abiotic factors, biomes
Species interactions: Antagonistic and mutualistic interactions.
Behavioural ecology: Sexual selection, animal behaviour, sociality, game theory.
Ecosystem ecology: Food webs, biogeochemical cycles, energy flow.
Biodiversity: key concepts.
Macroevolution: Reproductive isolation, macroevolutionary concepts
Conservation Biology: Global change, wildlife management and conservation.

TEXTBOOKS/REFERENCES

1. Molles, *Ecology: Concepts and Applications* ,4th Edition, McGraw-Hill, 2006
2. Futuyma, D., *Evolution*,Sinauer Associates, 2005

BIO 311 Microbiology [3003]

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

TEXTBOOKS/REFERENCES

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

BIO 312 Immunology [3003]

Immunology an overview: Innate and adaptive Immunity.
Antigen and antibody structure and function.
T and B cell development.

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

TEXTBOOKS/REFERENCES

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

BIO 313 Advanced Cell biology [3003]

Introduction to Cell Biology, Evolution of the Cell

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

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

DNA & chromosomes - packaging and organization.

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

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

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

Integrins, cadherins, selectins, immunoglobulin superfamily, and bacterial

adhesins.

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

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

Frontiers in Cell and molecular biology research.

TEXTBOOKS/REFERENCES

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

BIO 314 Evolutionary Ecology [3003]

Mechanisms of evolution

Evolution of the senses and sensory ecology

Signaling and communication in plants and animals

Asexual reproduction and the evolution of sex

Evolutionary perspectives in circadian rhythms and chronobiology

Population ecology and population genetics

Evolutionary consequences of species interactions

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

Community patterns II: niche theory, metapopulations and biodiversity

TEXTBOOKS:

1. N. B. Gotelli, *A primer of ecology*, 3^{rd} edition, Sinauer Associates, 2001
2. Charles W. Fox, Derek A. Roff, and Daphne J. Fairbairn, *Evolutionary ecology: concepts and case studies*, Oxford University Press, New York, 2001

BIO 321 Bacterial Genertics [3003]

Mutations and repair in bacteria (Classes of mutations, measuring mutations, mutator strains, mechanisms of bacterial DNA repair, SOS re-

sponse), Transposition, Mapping of mutations, Plasmids, Bacterial two-hybrid systems, Genetics of Bacteriophages, Recombination, Conjugation, Transformation, Transduction, Gene expression and regulation in bacteria, CRISPRs in bacteria.

TEXTBOOKS/REFERENCES

1. Larry Snyder, Molecular Genetics of Bacteria, 3rd Edition, ASM Press, Washington, USA.
2. Nancy Trun and Janine Trempy, Fundamental Bacterial Genetics, First Edition, Blackwell Science Ltd., USA, 2004.

BIO 322 Biophysics and Structural Biology [3003]

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

Conformational analysis:- Covalent interactions, non Covalent interactions and their roles in protein structure; Van der Waals radii of atoms (equilibrium separation between non covalently bonded atoms) - contact distance criteria; Noncovalent forces determining biopolymer structure; dispersion; forces; electrostatic interations; van der Waals interactions; hydrogen bonds; hydrophobic interactions; distortional energies; description of various interactions by potential functions; principles of minimization of conformational energy.

Introduction to bioinformatics:- Biological databases: Organisation, searching and retrieval of information, accessing global bioinformatics resources using the World Wide Web. -bio molecular databases - sequence databases - structural databases - details of organisation, access and deposition -

derived and specialised databases - data mining -homology v/s similarity - dot matrices - sequence comparison using Needleman and Wunsch method - Hash coding - BLAST and FASTA - Structure analysis - distance matrices -examples.

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

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

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

TEXTBOOKS/REFERENCES

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

BIO 323 Advanced Biochemistry [3003]

Exploring proteins and proteomics

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

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

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

Biosynthesis of amino acids, nucleic acids.

TEXTBOOKS/REFERENCES

1. Berg, Tymoczco, Stryer, *Biochemistry*, Freeman.
2. Lehninger, Cox and Nelson, *Principles of Biochemistry*, Freeman.

BIO 324 Neurobiology [3003]

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

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

Microbial Physiology: Structure of microbes, autotrophic and heterotrophic

metabolisms, growth and its control factors.

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

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

Cell-Cell communication in microbes.

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

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

TEXTBOOKS/REFERENCES

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

BIO 411 Developmental Biology [3003]

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

Commonly used experimental methods in developmental biology.

Generation and Interpretation of gradient information and Pattern formation.

Physics and Mathematics of morphogen gradients and their interpretation.

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

Growth and differentiation.

Evolution of body plan.

Stem cell biology and tissue repair.

Embryogenesis in plants: Genes controlling embryogenesis.

TEXTBOOKS/REFERENCES

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

BIO 412 Biostatistics [3003]

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

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

Hypothesis testing and experimental design.

Analysis of Variance and Covariance

Parametric and non-parametric statistics.

Multivariate Analysis: PCA, cluster; Time-series analysis

TEXTBOOKS/REFERENCES

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

BIO 413 Advances in Plant Biology [3003]

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

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

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

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

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

TEXTBOOK

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

BIO 414 Genomics [3003]

Anatomy of the genome, model genomes

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

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

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

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

Genomics and Medicine: Human genome sequencing, Personalized medicine.

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

TEXTBOOKS/REFERENCES

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

BIO 421 Mathematical and Systems Biology [3003]

Phase-plane analysis of ODE's; Enzyme kinetics; Derivation of Michaelis-Menten through a slow-fast analysis; Modelling in ecology and evolution; Reduction strategies for larger dimensional systems; Stochastic models

TEXTBOOKS/REFERENCES

1. Ermentrout, *Simulating, Analyzing, and Animating Dynamical Systems: A Guide to XPPAUT for Researchers and Students*
2. Keener and Sneyd, *Mathematical Physiology* Vol. 1 & 2
3. Edelstein-Keshet, *Mathematical Models in Biology*.
4. Alon, *Systems Biology* CRC Press 2007.

BIO422 Advanced Genetics [3003]

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

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

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

TEXTBOOKS/REFERENCES

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

BIO423 Advanced Molecular Biology [3003]

Gene Transcription.

Non-coding RNA.

Transcription regulation.

RNA processing.

Protein synthesis.

Protein folding.

Chromatin and gene expression.

Recombinant DNA technology

TEXTBOOKS/REFERENCES

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

List of Electives in Biology

1. Cancer Biology
2. Biodiversity
3. Animal Behaviour
4. Current topics in genetics and genomics
5. Plant Morphodynamics
6. Prokaryotic development
7. Viva-voce and treatise in Molecular Structural 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 Biochemistry[0031]

1. Estimation of Carbohydrates
2. Estimation of Nucleic acids
3. Estimation of Proteins
4. Estimation of Lipids
5. SDS Electrophoresis of proteins
6. Estimation of Amino acids
7. Analysis of Amino acids by Thin layer Chromatography and Paper Chromatography

BIO 212 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 222 Ecology [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 315 Advanced Lab-I [0093]

Ecology

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

Cell Biology

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

BIO 325 Advanced Lab-II [0093]

Biochemistry

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

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

Biophysics and structural biology

1. Basic UNIX commands, shell scripts and the first C-programming.

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

BIO 415 Advanced Lab-III [0093]

1. Plant Biology:Isolation of T-DNA insertion mutant defective in plant organ formation,
2. Tissue-specific expression studies in time and space
3. Genomics:Measurement of Mutation rates in genomes. Detection of genetic incompatibilities
4. Biostatistics:Exercises in Research Methodology, Statistical ecology, Sampling, Mathematical statistics.

Chemistry Syllabus

THEORY COURSES

CHY 111 Atomic Structure and Chemical Bonding [3103]

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

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

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

TEXTBOOKS/REFRENCES

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

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

CHY 121 Chemistry of Elements [3103]

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

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

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

TEXTBOOKS/REFRENCES

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

CHY 211 Chemical Reactions and Reactive Intermediates [3103]

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

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

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

TEXTBOOKS/REFRENCES

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

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

CHY 221 Principles of Physical Chemistry [3103]

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

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

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

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

TEXTBOOK

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

CHY 311 Advanced Coordination Chemistry [3003]

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

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

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

Crown ethers and cryptands and their complexation properties with metal ions, coordination polymers, metal-organic framework (MOF) compounds,

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

TEXTBOOKS/REFRENCES

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

CHY 312 Quantum Chemistry [3003]

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

Exactly Solvable Problems: free particle, quasi-free particle (1-D, 2-D and 3-D box problems), concepts of quantum numbers and degeneracies, applications in organic metals, quantum wells and dots, the simple harmonic

oscillator, angular momentum, the hydrogen atom problem, atomic orbitals, quantum tunneling and scattering.

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

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

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

TEXTBOOKS/REFRENCES

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

CHY 313 Stereochemistry: Principles and Applications [3003]

Concept of chirality, Fisher projection formula, sequence rule, R and S notations in cyclic and acyclic compounds, optical isomerism of compounds containing one or more asymmetric carbon atoms; Stereochemistry of biphenyls, allenes, spirans etc., conditions for optical activity, R and S notations, stereochemistry of other cyclic molecules, atropisomerism, chirality due to folding of helical structures.

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

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

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

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

TEXTBOOKS/REFRENCES

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

CHY 314 Instrumental Methods [3003]

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

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

ing chamber etc.).

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

TEXTBOOKS/REFRENCES

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

CHY 321 Organometallic Chemistry [3003]

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

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

Fluxional organometallic compounds, nature of non-rigidity and their characterization by NMR spectroscopy, activation of small molecules by

metal ions, reactions of coordinated ligands, synthetic and catalytic aspects of organometallic compounds, oxidative addition reactions and reductive elimination reactions, migratory insertion reactions, 1,1-migratory insertion reaction, 1,2-insertion and β-hydride elimination reactions, cyclometallation, Wilkinson's catalyst and alkene hydrogenation, Tolman catalytic loops, water-gas shift reaction, hydroformylation reactions and Heck and Breslow mechanism, Wacker process of catalytic addition of molecular oxygen to alkenes, synthetic gasoline, Ziegler-Natta polymerization of alkenes, Fischer-Tropsch process, alkene metathesis, oligomerisation of alkynes, metallacycles, ortho-metallation.

TEXTBOOKS/REFERENCES

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

CHY 322 Advanced Molecular Spectroscopy [3003]

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

Interaction of radiation with matter: Electromagnetic radiation, radiation

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

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

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

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

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

TEXTBOOKS/REFRENCES

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

CHY 323 Advanced Organic Chemistry I [3003]

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

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

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

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

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

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

TEXTBOOKS/REFRENCES

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

CHY 324 Spectroscopic methods in structure determination [3003]

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

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

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

TEXTBOOKS/REFRENCES

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

CHY 411 Chemistry of Solids and Materials [3003]

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

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

Electronic Structure of Solids: Free electron theory, Drude model, concept of Fermi level, density of states, band structure, periodic potentials in

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

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

TEXTBOOKS/REFRENCES

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

SUGGESTED READING

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

CHY 412 Advanced Chemical Kinetics [3003]

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

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

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

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

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

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

TEXTBOOKS/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*, 2nd Ed.

Supplementary Reading:

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

CHY 422 Physical Organic Chemistry [3003]

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

TEXTBOOKS/REFRENCES

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

Supplementary Reading:

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

CHY 423 Advanced Organic Chemistry III [3003]

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

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

References:

TEXTBOOKS/REFRENCES

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

List of Electives in Chemistry

1. Computational Chemistry

Computational Chemistry [3003]

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

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

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

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

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

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

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

TEXTBOOKS/REFRENCES

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

LABORATORY COURSES

CHY 112 Chemistry Lab-I[0031]

1. Qualitative inorganic salt analysis containing two anions and two cations (5 mixtures)
2. Inorganic preparations
   (a) Preparation of potash alum from scrap aluminium
   (b) Preparation of hexamineNi(II)chloride
   (c) Preparation of tetramineCu(II)sulphate
3. Organic preparations
   (a) Preparation of paracetamol
   (b) Preparation of aspirin
4. Introduction to Chromatography
   (a) Separation of metallic ions using paper chromatography
   (b) Separation of plant extracts using thin layer chromatography
5. Introduction to colorimetry using photoelectric colorimeter

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

6. Introduction to titrimetric analysis (acidimetry and alkalimetry)

(a) Estimation of antacid capacity of antacid

CHY 122 Chemistry Lab-II [0031]

1. Permanganometry

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

2. Dichrometry

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

3. Iodometry

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

4. Iodimetry

(a) Estimation of ascorbic acid in fruit juice

5. Argentometry

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

6. Complexometry

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

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

7. Gravimetric Analysis

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

CHY 212 Chemistry Lab-III [0031]

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

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

6. Organic estimations

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

CHY 222 Chemistry Lab-IV [0031]

1. Phenol water system:

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

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

2. Distribution Ratio:

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

3. Solid liquid equilibrium:

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

4. Transition temperature:

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

5. Three component system

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

6. Chemical kinetics

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

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

7. Conductometric titration

- Conductometric titration of
- Strong acid >< Strong base
- Strong acid >< Weak base
- Weak acid >< Strong base
- Precipitation titration

8. Estimation using conductometric titrations

- Mixture of hydrochloric acid and acetic acid
- Mixture of hydrochloric acid and oxalic acid
- Mixture of acetic acid and oxalic acid
- Mixture of sulphuric acid, acetic acid and copper sulphate

9. Potentiometric titration

- HCl >< NaOH using quinhydrode as the indicator electrode
- Orthophosphoric acid >< NaOH using quinhydrode as the indicator electrode
- Mixture of KCl, KBr and KI using silver electrode
- Ferrous ammonium sulphate >< Potassium dichromate using Pt electrode

CHY 315 Advanced Organic Chemistry Laboratory[0093]

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

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

CHY 325 Advanced Inorganic Chemistry Laboratory[0093]

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

CHY 415 Advanced Physical Chemistry Laboratory[0093]

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

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

3. Surface tension

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

4. Thermochemistry

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

5. Refractometry

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

6. Spectophotometry

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

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

7. Dipole measurement

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

8. Equilibrium and dissociation constant

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

9. Chemical Kinetics

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

10. Electrolytic conductance

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

11. Transport number

- Determination of transport number by moving boundary and Hitroff methods

12. Electromotive force

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

13. Surface Chemistry

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

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

Mathematics Syllabus

MAT 111 Introduction to Algebra [3103]

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

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

TEXTBOOKS/REFERENCES

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

MAT 121 Introductory Analysis - I [3103]

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

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 211: Introductory Analysis II [3103]

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

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 221: Introduction to Statistics [3103]

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 311: Real Analysis [3003]

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 312: Discrete Mathematics [3003]

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 313: Abstract Algebra [3003]

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 314: Advanced Linear Algebra [3003]

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

adjoint operators.

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

TEXTBOOKS/REFERENCES

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

MAT 315: Numerical Analysis [3003]

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 321: Complex Analysis [3003]

PREREQUISITE

1. MAT 311-Real Analysis

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 322: Measure Theory and Integration [3003]

PREREQUISITE

1. MAT 311-Real Analysis

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 323: Galois Theory and Commutative Algebra [3003]

PREREQUISITE

1. MAT 313-Abstract Algebra

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 324: Multivariate Analysis [3003]

PREREQUISITES

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 325: General Topology [3003]

PREREQUISITE

1. MAT 311-Real Analysis

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 411: Functional Analysis [3003]

PREREQUISITES

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

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 412: Probability Theory and Random Processes [3003]

PREREQUISITE

1. MAT 322-Measure Theory and Integration

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 413: Number Theory and Cryptography [3003]

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 414: Theory of Ordinary Differential Equations [3003]

PREREQUISITE

1. MAT 311-Real Analysis

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 421: Advanced Analysis [3003]

PREREQUISITE

1. MAT 411-Functional Analysis

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

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

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

TEXTBOOKS/REFERENCES

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

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

MAT 422: Partial Differential Equations [3003]

PREREQUISITES

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

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

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

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

TEXTBOOKS/REFERENCES

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

MAT 423: Combinatorics and Graph Theory [3003]

PREREQUISITE

1. MAT 313-Discrete Mathematics

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

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

TEXTBOOKS/REFERENCES

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

MAT 424: Differential Geometry [3003]

PREREQUISITE

1. MAT 324-Multivariate Analysis

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

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

Submersion and Immersion: Submersion, Immersion and embeddings.

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

TEXTBOOKS/REFERENCES

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

Partial List of Electives

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

Physics Syllabus

THEORY COURSES

PHY 111 Mechanics [3103]

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

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

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

TEXTBOOKS/REFERENCES

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

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

PHY 121 Electromagnetic Theory [3103]

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

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

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

TEXTBOOKS/REFERENCES

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

PHY 211 Optics

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

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

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

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

TEXTBOOKS/REFERENCES

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

PHY 221 Thermal and Statistical Physics [3103]

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

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

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

TEXTBOOKS/REFERENCES

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

PHY 311 Mathematical Methods in Physics [3003]

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

Partial Differential equations: Classification of PDE's. Hyperbolic equa-

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

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

TEXTBOOKS/REFERENCES

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

PHY 312 Classical Mechanics [3003]

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

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

TEXTBOOKS/REFERENCES

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

PHY 313 Electronics - 1 [3003]

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

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

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

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

TEXTBOOKS/REFERENCES

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

PHY 314 Quantum Mechanics - 1 [3003]

Quantum kinematics: The state vector, Dirac Bra and Ket notation, the principle of superposition, the Stern-Gerlach experiment. Hilbert space and some general properties of linear vector spaces, Rays and vectors in Hilbert space, Normalization, Basis vectors. Non commutating operators and observables, the uncertainty principle, Operators, eigenvalues, eigenvectors, observables and expectation values (a bit of linear algebra), Quantum amplitudes, probabilities and the Born rule. A basis labeled by a continuous parameter and the wave function, The position and momentum bases, Fourier transforms, Delta function normalization, Function spaces, The uncertainty principle revisited, The probability current and the continuity equation.

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

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

TEXTBOOKS/REFERENCES

1. 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 - 1 [3003]

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

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

TEXTBOOKS/REFERENCES

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

PHY 323 Electronics 2 [3003]

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

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

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

TEXTBOOKS/REFERENCES

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

PHY 324 Electrodynamics and special theory of relativity [3003]

Review of Maxwell's equations and basic electrodynamics.

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

PHY 411 Experimental Methods [3003]

Electrical characterization techniques: Resistance measurement, various configurations (2/4 probe, van der pauw). AC/DC techniques range of

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

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

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

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

Magnetometer (VSM) and SQUID magnetometer; Measurement of heat capacities.

TEXTBOOKS/REFERENCES

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

PHY 412 Condensed Matter Physics - 2 [3003]

PREREQUISITE

1. PHY 322: Condensed Matter Physics - 1

Semiconductors: intrinsic and extrinsic semiconductors, hole, effective mass, laws of mass action, electron and hole mobilities, impurity band conduction , p-n junction , Shottky barrier , quantum Hall effect ; Crystal defects: Schottky vacancies, Frenkel defects, F-center etc; Optical Processes: Optical reflectance, Kramers-Kronig relations, Electronic interband transitions, Frenkel excitons, Mott-Wannier excitons, Raman effect in crystals etc.

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

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

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

TEXTBOOKS/REFERENCES

1. Michael P. Marder, *Condensed matter physics*, John Wiley, 2000.
2. N. W. Ashcroft, N. David Mermin, *Solid state physics*, Harcourt, 1976.

3. C. Kittel, *Introduction to solid state physics*, 7^{th} edition, John Wiley, 2004.
4. A. J. Dekker, *Solid state physics*, Macmillan India, 2005.

PHY 413 Quantum Mechanics - 2 [3003]

PREREQUISITES

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

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

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

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

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

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

Symmetry considerations in Scattering; Time-dependent formulation of Scattering; Inelastic Electron-Atom Scattering.

TEXTBOOKS/REFERENCES

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

PHY 421 High Energy Physics [3003]

PREREQUISITE

1. PHY 413: Quantum Mechanics - 2

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 - 2

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.

List of Electives in Physics

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

LABORATORY COURSES

PHY 112 Experiments in Mechanics [0031]

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

PHY 122 Experiments in electrodynamics [0031]

1. Potentiometer Internal Resistance of Cell
2. Magnetic field along the axis of Circular Coil
3. Deflection Magnetometer
4. Conversion of Galvanometer to Voltmeter
5. Ballistic Galvanometer Capacitance
6. Spot Galvanometer High Resistance
7. Diode Characteristics & Gates using Diodes
8. Diode Rectifiers
9. Zener Diode Voltage Regulator
10. Electronics using MultiSim and NI Interface

PHY 212 Experiments in Optics [0031]

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

8. Liquid Lens
9. Reflection Grating
10. Polarization Malus Law

PHY 222 Experiments on Heat and Thermodynamics [0031]

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

PHY 315 Advanced Physics Experiments I [0093]

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

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

PHY 325 Advanced Physics Experiments II [0093]

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

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

PHY 415 Advanced Physics Experiments III [0093]

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

Interdisciplinary courses

IDC 111: Mathematical Tools 1 [2023]

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

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

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

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

gence and curl.

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

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

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

PRACTICAL COMPONENT: Plotting of familiar functions in the complex plane

TEXTBOOKS

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

IDC 121: Mathematical Tools 2 [2023]

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

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

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

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

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

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

TEXTBOOKS

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

IDC 211 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*.

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