ACADEMICS AT IISER BHOPAL

The Indian Institute of Science Education and Research (IISERs) (founded at Bhopal, Kolkata, Mohali, Pune and Thiruvananthapuram) firmly believe in providing a resolute platform to promote basic sciences and meet the growing demands of enthusiastic science aspirants in India.

IISER Bhopal was established in 2008 by the Ministry of Human Resource Development (MHRD), Government of India. The primary focus of the Institute is to integrate quality science education and research. The institute is committed to imparting high moral, ethical and social values coupled with generating environmental awareness amongst one and all.

IISER Bhopal offers five year BS-MS (Dual Degree) programme in Biology, Chemistry, Physics and Mathematics. All courses in the first two years are common and mandatory to all students. Students will be allowed to choose major in a discipline of their choice from the beginning of the third year.

Currently, candidates are admitted after 10+2 having qualified one of the following criteria:

- IIT-JEE Main Merit List
- Kishore Vaigyanik Protsahan Yojna (KVPY) organized by IISc Bangalore
- Direct admission from top 1% of state board qualified candidates as approved by DST, India.

All selected students are awarded INSPIRE fellowship of Rs 5000/- pm by the Government of India.

IISER Bhopal also offers PhD programme in Biology, Chemistry, Earth and Environmental Sciences, Mathematics and Physics. A prospective candidate should have completed postgraduate programme (MS/MSc/MTech/MBBS) in relevant discipline along with a valid GATE score or CSIR/UGC/NET-JRF or other equivalent examination. All selected candidates are awarded fellowship as applicable under DST/CSIR norms.

Course Structure for the BS-MS (Dual Degree) and Ph. D Programmes

BS-MS (Dual Degree) programme consists of core courses and professional courses. The core courses are for the first four semesters and courses from all the four science departments will be offered along with interdisciplinary courses. Each semester will have at least one interdisciplinary course. This is to broaden the students' exposure on various subjects. All the courses offered under core courses are common and compulsory to all the BS-MS (Dual Degree) students.

From the third year onwards, students will choose a discipline in which they would like to specialize. These departmental courses are arranged discipline-wise in alphabetical order. To major in a particular discipline, in each semester, the student has to take all the compulsory courses from that department. These courses are called professional courses.

There are a few other courses called departmental electives and open electives. In departmental electives a student has the choice to select courses from the department in which he/she is majoring. For open electives, a student is free to choose a course from any discipline including his/her major.

Ph. D programme is designed to include course work, comprehensive examination, state-of-the-art seminar, and research work in the form of a dissertation and oral defense of the research work.

This document comprises of all the courses offered at IISER Bhopal and their contents for both the BS-MS (Dual Degree) and Ph. D course work.

Alpha-numeric Notation for Courses:

1. Subjects:

BIO	Biology
CHM	Chemistry
CS	Computer Science
EES	Earth and Environmental Science
HSS	Humanities and Social Sciences
IDC	Interdisciplinary Course
MTH	Mathematics
PHY	Physics

2. Three Digit Numbers:
First digit from left denotes the year in which the course is offered(1 to 6).

Second and third digits in chemistry are assigned to sub-discipline wise, i.e., 1 to 20 are assigned to inorganic chemistry, 21 to 40 to organic chemistry and 41 to 60 to physical chemistry courses, whereas in other departments, second and third digits give the course number of a particular course.

Third digit indicates the semester, e.g., odd digits depict the odd semester and even digits depict the even semester, applicable for undergraduate courses only.

3. Example:

- *CHM 411 means that it is an inorganic chemistry course offered in the first semester of the fourth year.*
- *Similarly, MTH 302 means that it is a mathematics course offered in the second semester of the third year.*

CORE COURSES

1st Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
BIO 101	Chemical Biology	3	0	1	6	3
CHM 101	General Chemistry I: Inorganic Molecules	3	0	1	6	3
MTH 101	Calculus of One Variable	3	0	1	6	3
PHY 101	Mechanics	3	0	1	6	3
BIO 103	General Biology Laboratory I	0	3	0	0	1
CHM 103	Inorganic Chemistry Laboratory	0	3	0	0	1
PHY 103	General Physics Laboratory I	0	3	0	0	1
HSS 101	English and Communication	3	0	0	6	3
CS 101	Introduction to Computers	1	3	0	2	2
Total		16	12	4	32	20

2nd Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
BIO 102	Biological Organization	3	0	1	6	3
CHM 112	General Chemistry II: Organic Molecules	3	0	1	6	3
MTH 102	Linear Algebra	3	0	1	6	3
PHY 102	Electromagnetism & Optics	3	0	1	6	3
BIO 104	General Biology Laboratory II	0	3	0	0	1
CHM 114	Organic Chemistry Laboratory	0	3	0	0	1
PHY 104	General Physics Laboratory II	0	3	0	0	1
HSS 102	HSS/IDC	3	0	0	6	3
Total		15	9	4	30	18

3rd Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
BIO 201	Biological Processes	3	0	1	6	3
CHM 241	General Chemistry III: Chemical Thermodynamics and Kinetics	3		1	6	3
MTH 201	Multivariable Calculus and Differential Equations	3	0	1	6	3
PHY 201	Quantum Physics	3	0	1	6	3
BIO 203	General Biology Laboratory III	0	3	0	0	1
CHM 223	Physical Chemistry Laboratory	0	3	0	0	1
PHY 203	General Physics Laboratory III	0	3	0	0	1
HSS 201	Economics/Government	3	0	0	6	3
Total		15	9	4	30	18

4th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
BIO 202	Computational Biology	3	3	0	6	4
CHM 222	Introduction to Spectroscopy	3	0	1	6	3
MTH 202	Complex Variables	3	0	1	6	3
PHY 202	Electronics	3	0	1	6	3
PHY 204	Electronics Laboratory	0	3	0	0	1
HSS 202		3	0	0	6	3
EES 202	Atmospheric Sciences	3	0	0	6	3
Total		18	6	3	36	20

Lec Hr: Lecture Hour; Lab Hr: Laboratory Hour; Tut Hr: Tutorial Hour; SS Hr: Self Study Hour

- Every Lecture Hour is associated with a certain number of Self Study Hours
- Tutorials will have no credits
- Number of Credits = [(Lec Hr + Lab Hr + SS Hr)/3]
- All laboratory work (including notebook writing) should be completed inside the laboratory

For example, CHM 222 has 3 Lec Hr and 6 SS Hr
So, Number of Credits = [(3+0+6)/3] = 3

Annexure II

PROFESSIONAL COURSES

(BIOLOGY MAJOR)

5th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
BIO 301/601	Biochemistry	3	0	0	9	4
BIO 303	Genetics	3	0	0	6	3
BIO 305	Animal Physiology	3	0	0	6	3
BIO 307	Biology Laboratory I	0	6	0	0	2
*** ***	Open Elective I	3	0	0		
*** ***	Open Elective II	3	0	0		
Total		15	6	0		

6th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
BIO 302	Cell Biology	3	0	0	6	3
BIO 304/602	Molecular Biology	3	0	0	9	4
BIO 306	Plant Physiology	3	0	0	6	3
BIO 308	Biology Laboratory II	0	6	0	0	2
*** ***	Open Elective III	3	0	0		
*** ***	Open Elective IV	3	0	0		
Total		15	6	0		

7th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
BIO 401	Immunology	3	0	0	6	3
BIO 403/603	Microbiology	3	0	0	9	4
BIO 405	Biology Laboratory III	0	6	0	0	2
BIO ***	Departmental Elective I	3	0	0	9	4
*** ***	Open Elective V	3	0	0		
*** ***	Open Elective VI	3	0	0		
Total		15	6	0		

8th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
BIO 402/604	Structural Biology	3	0	0	9	4
BIO 404	Neurobiology	3	0	0	6	3
BIO 406/606	Cancer Biology	3	0	0	9	4
BIO ***	Departmental Elective II	3	0	0	9	4
BIO ***	Departmental Elective III	3	0	0	9	4
*** ***	Open Elective VII	3	0	0		
Total		18	0	0		

9th Semester

Course No.	Course Name	Credit
BIO 501	Thesis Research	18
Total		18

10th Semester

Course No.	Course Name	Credit
BIO 501	Thesis Research	18
Total		18

NOTE:

1. To **Minor** in any discipline, the student has to take a **minimum of 14 Credits** (at least 4 open electives) of that particular discipline

2. After the mid semester examination of the eighth semester, students will be assigned a supervisor for the ninth and the tenth semesters for doing **Thesis Research**

3. Minimum number of credits for getting a BS-MS Dual degree is 185. A student must clear all the courses opted for.

4. All laboratory work should be finished inside the laboratory including laboratory notebook writing.

(CHEMISTRY MAJOR)

5th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
CHM 301/601	Symmetry and Group Theory	3	0	0	9	4
CHM 311	Organic Chemistry I	3	0	0	6	3
CHM 321/621	Principles of Quantum Mechanics	3	0	0	9	4
CHM 313	Organic Chemistry Laboratory	0	6	0	0	2
*** ***	Open Elective I	3	0	0		
*** ***	Open Elective II	3	0	0		
Total		15	6	0		

6th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
CHM 302	Chemistry of Main Group Elements	3	0	0	6	3
CHM 322	Organic Chemistry II	3	0	0	6	3
CHM 322/622	Statistical Thermodynamics and Rate Theories	3	0	0	9	4
CHM 304	Inorganic Chemistry Laboratory	0	6	0	0	2
*** ***	Open Elective III	3	0	0		
*** ***	Open Elective IV	3	0	0		
Total		15	6	0		

7th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
CHM 401	Chemistry of Transition Elements	3	0	0	6	3
CHM 411/611	Physical Organic Chemistry	3	0	0	9	4
CHM 441/643	Theory of Modern Physical Methods	3	0	0	9	4
CHM 443	Physical Chemistry Laboratory	0	6	0	0	2
CHM ***	Departmental Elective I	3	0	0	9	4
*** ***	Open Elective V	3	0	0		
Total		15	6	0		

8th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
CHM 402/602	Applications of Modern Physical Methods	3	0	0	9	4
CHM 442/644	Chemical Binding	3	0	0	9	4
CHM ***	Departmental Elective II	3	0	0	9	4
CHM ***	Departmental Elective III	3	0	0	9	4
*** ***	Open Elective VI	3	0	0		
*** ***	Open Elective VII	3	0	0		
Total		18	0	0		

9th Semester

Course No.	Course Name	Credit
CHM 501	Thesis Research	18
Total		18

10th Semester

Course No.	Course Name	Credit
CHM 501	Thesis Research	18
Total		18

NOTE:

1. To **Minor** in any discipline, the student has to take a **minimum of 14 Credits** (at least 4 open electives) from that particular discipline.

2. After the mid-semester examination of the 8^{th} semester, students will be assigned a supervisor for their Thesis Research.

3. Minimum number of credits for getting a BS-MS Dual degree is 185. A student must clear all the courses opted for.

4. All laboratory work should be completed during the laboratory hours including notebook writing.

5. Provisions for departmental electives in the 9^{th} and 10^{th} semesters for those students who choose theoretical chemistry as their research area.

(MATHEMATICS MAJOR)

5th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
MTH 301	Groups and Rings	3	0	0	9	4
MTH 303	Real Analysis - I	3	0	0	9	4
MTH 305	Foundations of Mathematics and Elementary Number Theory	3	0	0	9	4
MTH ***	Departmental Elective I	3	0	0	9	4
*** ***	Open Elective I	3	0	0		
Total		15	0	0		

6th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
MTH 302	Modules and Fields	3	0	0	9	4
MTH 304	Metric Spaces and Topology	3	0	0	9	4
MTH 306	Ordinary Differential Equations	3	0	0	9	4
MTH ***	Departmental Elective II	3	0	0	9	4
*** ***	Open Elective II	3	0	0		
Total		15	0	0		

7th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
MTH 403	Real Analysis II	3	0	0	9	4
MTH 405	Partial Differential Equations	3	0	0	9	4
MTH 407	Probability and Statistics	3	0	0	9	4
MTH ***	Departmental Elective III	3	0	0	9	4
*** ***	Open Elective III	3	0	0		
Total		15	0	0		

8th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tu t Hr	SS Hr	Credit
MTH 402	Galois Theory	3	0	0	9	4
MTH 404	Measure and Integration	3	0	0	9	4
MTH 406	Differential Geometry of Curves and Surfaces	3	0	0	9	4
MTH ***	Open Elective IV	3	0	0	9	4
*** ***	Open Elective V	3	0	0		
Total		15	0	0		

9th Semester

Course No.	Course Name	Credit
MTH 501	Thesis Research	12
MTH ***	Departmental Elective IV	4
MTH ***	Departmental Elective V	4
Total		20

10th Semester

Course No.	Course Name	Credit
MTH 501	Thesis Research	12
MTH ***	Departmental Elective VI	4
MTH ***	Departmental Elective VII	4
Total		20

NOTE:

1. To **Minor** in any discipline, the student has to take a **minimum of 14 Credits** (at least 4 open electives) from that particular discipline.

2. After the mid-semester examination of the 8th semester, students will be assigned a supervisor for their Thesis Research.

3. Minimum number of credits for getting a BS-MS Dual degree is 185. A student must clear all the courses opted for.

(PHYSICS MAJOR)

5th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
PHY 301	Mathematical Methods I	3	0	0	9	4
PHY 303	Quantum Mechanics I	3	0	0	9	4
PHY 305/601	Classical Mechanics	3	0	0	9	4
PHY 307	Physics Laboratory I	0	6	0	3	3
*** ***	Open Elective I	3	0	0		
Total		12	6	0		

6th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
PHY 302	Mathematical Methods II	3	0	0	9	4
PHY 304	Quantum Mechanics II	3	0	0	9	4
PHY 306/602	Statistical Mechanics	3	0	0	9	4
PHY 308	Physics Laboratory II	0	6	0	3	3
*** ***	Open Elective II	3	0	0		
Total		12	6	0		

7th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
PHY 401/603	Electrodynamics and Special Theory of Relativity	3	0	0	9	4
PHY 403/605	Condensed Matter Physics	3	0	0	9	4
PHY 405	Condensed Matter Physics Laboratory	0	6	0	3	3
*** ***	Open Elective III	3	0	0		
*** ***	Open Elective IV	3	0	0		
Total		12	6	0		

8th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
PHY 402	Atomic and Molecular Physics	3	0	0	9	4
PHY 404	Nuclear and Particle Physics	3	0	0	9	4
PHY 406	Nuclear Physics Laboratory	0	6	0	3	3
*** ***	Open Elective V	3	0	0		
*** ***	Open Elective VI	3	0	0		
Total		12	6	0		

9th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
PHY 6**	Departmental Elective I	3	0	0	9	4
PHY 6**	Departmental Elective II	3	0	0	9	4
PHY 501	Thesis Research					14
Total		6	0	0	18	22

10th Semester

Course No.	Course Name	Lec Hr	Lab Hr	Tut Hr	SS Hr	Credit
PHY 6**	Departmental Elective III	3	0	0	9	4
PHY 6**	Departmental Elective IV	3	0	0	9	4
PHY 501	Thesis Research					14
Total		6	0	0	18	22

NOTE:

1. To **Minor** in any discipline, the student has to take a **minimum of 14 Credits** (at least 4 open electives) from that particular discipline.

2. After the mid-semester examination of the 8th semester, students will be assigned a supervisor for their Thesis Research.

3. Minimum number of credits for getting a BS-MS Dual degree is 185. A student must clear all the courses opted for.

4. All laboratory work should be completed during the laboratory hours including notebook writing.

COURSE CONTENTS

BIOLOGY (3)

BIO 101: Chemical Biology

[No. of Lectures: 40-42]

Chemical Biology: chemical composition of living system.

- Elemental and biomolecular composition of living system.
- Chemical properties of biomolecules
- Amino acids, sugars, lipids, nucleotides
- Biopolymers – proteins, nucleic acids, polysaccharides and Biomembranes
- Separation and analytical techniques.

Suggested Reading

- Biochemistry (5th Edition) by Jeremy Berg, John Tymoczko and Lubert Stryer,
- Biochemistry (3rd Edition) by Donald J. Voet and Judith G. Voet.
- Lehninger Principles of Biochemistry (4th Edition) by David L. Nelson andMichael M. Cox.

BIO 103: General Biology Laboratory I (1)

- Sterilization methods
- Gram staining of bacteria
- Isolation of pure culture
- Estimation of proteins by Bradford method
- Mitosis from Onion tip
- Demonstration of electrophoresis (Agarose and SDS-PAGE)
- pH buffers etc
- Estimation of proteins by Lowry's method
- Estimation of nucleic acids
- Carbohydrates and lipid analysis

BIO 102: Biological Organization (3)

[No. of Lectures: 40-42 lectures]

Biological Organization – structure-function relationship; macroscopic to microscopic view of biomolecules.

- Hierarchal view of biological organisation.
- Structure and function of molecules, supramolecular assemblies, cells and tissues
- Examples of membrane function once it is assembled – thematic link to the original principle of emergent properties. The course would emphasize examples of such properties emerging at different hierarchal level of organization.
- Supramolecular assemblies including molecular motors, ribosome, catalytic antibodies, virus.

Suggested Reading

- Animal Physiology by Hill, Wyse & Anderson **2004**
- Animal physiology by Randall Burggren & French **2005**
- Guyton text book of Medical physiology

BIO 104: General Biology Laboratory II (1)

- Carbohydrate test
- Protein test
- Lipid test
- Determination of fat value
- Blood group testing
- Size exclusion Chromatography
- Isolation of sub-cellular components: biochemical fractionation
- Aminoacid separation by TLC
- Preparation of chromosome
- Chloroplast preparation

BIO 201: Biological Processes (3)

[No. of Lectures: 40-42]

Biological Processes: Energetics, exchange and movement.

- Energetics of living system : metabolism and energy – photosynthesis, cellular respiration, translation of energy into osmotic work, mechanical, biosynthesis and assembly work.
- Cellular and molecular basis of gas exchange – oxygen transport (haemoglobin vs myoglobin)
- Movement – molecular basis of cellular movement.

Suggested Reading

- Animal Physiology by Hill, Wyse & Anderson **2004**
- Animal physiology by Randall Burggren & French **2005**
- Guyton text book of Medical physiology

BIO 203: General Biology Laboratory III (1)

- Antibiotic sensitivity test of bacteria.
- Bacterial growth curve/kinetics
- Isolation of DNA from Yeast and electrophoresis.
- Preparation of bacterial competent cells
- Plasmid transformation in bacteria
- Plasmid transformation in yeast
- Isolation of plasmid DNA
- Restriction digestion of DNA
- Preparation of cell extract and Western blotting
- Polymerase chain reaction

BIO 202: Computational Biology (4)

[No. of Lectures: 40-42]

Computational Biology - Storage and information transfer in Biological system.

- Central Dogma of Molecular Biology
- Biological databases
- Elements of probability and statistics
- Phylogenetic analysis
- Gene prediction and analysis
- Sequence alignment

BIO 301/601: Biochemistry (4)

No. of Lectures: 40-42]

- Metabolism: Basic concepts, Central role of ATP in metabolism, Carbon fuel and its its oxidation, Concept of energy rich compounds and intermediates, Common types of reactions involved in metabolism.
- Glycolysis and gluconeogenesis, Energetics and ATP productions.
- Regulation of glycolysis, glycogen synthase, metabolic flux and its regulation by various metabolic intermediates.
- TCA cycle, its regulation, its role in energy generation, its role in generating biosynthetic intermediates, glyoxylate cycle.
- Redox reaction, mitochondrial structure and its role in energy metabolism, electron transport system.
- ATP synthesis and chemoosmotic hypothesis of ATP generation.
- Pentose phosphate pathway and its importance in biosynthetic reactions.
- Glycogen synthesis, breakdown and its regulation.

- Fatty acid biosynthesis and degradation.
- Synthesis and degradation of steroids.
- Amino acid metabolism, Urea cycle, one carbon reaction, non protein amino acids, amines and their role in cell function.
- Nucleotide biosynthesis and metabolism, salvage pathways, its regulation and diseases.
- Special topics in biochemistry. Mechanisms of hormone action, Role of posttranslation modifications of proteins in regulation of cell function, Muscle contraction and cell motility.

Suggested Reading

- Biochemistry (5th Edition) by Jeremy Berg, John Tymoczko and Lubert Stryer,
- Biochemistry (3rd Edition) by Donald J. Voet and Judith G. Voet.
- Lehninger Principles of Biochemistry (4th Edition) by David L. Nelson and Michael M. Cox.

BIO 303: Genetics (3)

[No. of Lectures: 40-42]

- History of genetics, principles. Concept of genes, alleles, mutants. Sex linkage, haploid and diploid genetics. Mandelian inheritance, genetic linkage. Chromosomal basis of inheritance.
- Life cycles and advantages of the following organisms commonly used in genetic studies: T4 and Lambda phages, *Neurospora*, *E.coli*, *Saccharomyces cerevisea* and *Schizosaccharomyces pombe*, *Caenorhabditis*, *Drosophila*, *Danio rerio, Mus musculus.* Conventions of nomenclature of genes and gene products in different model systems.

- Complementation tests: intergenic and intragenic complementation. Dominant negative phenotype, epistasis, penetrance and expressivity.
- Molecular basis of phenotypes: Genetics as a study of how proteins fold function and interact. Second site suppression, nonsense suppression, synthetic lethality, conditional alleles, silent mutations.
- Chromosomal anomalies: Numerical, Structural. Meiosis in inversion and translocation heterozygotes; breakage-fusion-bridge cycles. Induced chromosomal aberrations in somatic cells. Sister chromatid exchanges and somatic crossing over. Dosage compensation in *Caenorhabditis*, *Drosophila* and mammals.
- Mutagenesis & DNA repair: Endogenous and exogenous origins of DNA damage, Types of DNA damage, DNA repair pathways, Error-prone repair and mutagenesis, Damage signaling and checkpoint arrest, Detection and isolation of mutations. DNA testing: Direct testing, Screening for unknown mutations, Detection of known mutations, Indirect testing – gene tracking, DNA profiling: establishing identity and relationships, Population screening - ethics, organization and advantages.
- Genetic drift, Selection (Types of selection, selection coefficient, selection in natural populations). Chromosomal, DNA and allozyme polymorphism in natural population.
- DNA-based phylogenetic trees, Human phylogeny, Molecular phylogenetics of *Homo sapiens.*
- Human genetics: Non mandelian inheritance. Diseases loci and pedigrees. Mapping with RNA markers. Simple vs complex traits. Dynamics/imprinting. Mechanisms of imprinting.

Recombinant DNA technology: Definition, importance and applications of recombinant DNA technology. Cloning, different kinds of vectors. Restriction endonucleases and restriction mapping. Polymerase chain reaction, DNA sequencing methods. DNA finger printing and its applications in forensic science.

Suggested Reading

- B. Lewin, Genes VIII, Prentice-Hall, New Jersey.
- S.B. Primrose and R. Twyman, Principles of genome analysis and genomics (3rd edition), Blackwell
- T.A. Brown, Genetics: A molecular approach (3rd adition), BIOS scientific publisher.
- M.J. Pelczar Jr., Microbiology, Tata McGraw-Hill, New Delhi.
- U.N. Streips and R.E. Yasbin (Editors), Modern Microbial genetics (2nd edition), John Wiley, New York.
- T. Strachan and A.P. Read, Human Molecular genetics (2nd edition), John Wily, New York.
- Griffiths, Wessler, Lewonthin, Gelbert, Suzuki and Miller, Introduction to genetic analysis (8th edition), W.H. Freeman, New York.
- R.F. Weaver and P.W. Hedrick, Genetics (3rd edition), Willium C. Brown.
- L.M. Prescott, Microbiology (6th edition), McGraw-Hill, New York

BIO 305: Animal Physiology (3)

[No. of Lectures: 40-42]

- Tissue system and their functions: Epithelial tissue, Connective tissue, muscular tissue and nervous tissue.
- Principles of physiology: relationship between structure and function, Adaptation, acclimatization,

Acclimation, Homeostasis, Feedbackcontrol systems, Conformity and regulation.

- Methods for exploring physiological mechanisms: Molecular techniques, Cellular techniques, biochemical techniques, Techniques for studying behavior.
- Endocrine system: Glands and Hormones: Secretory mechanisms, Endocrine and neuroendocrine systems. Cellular mechanism of hormone action. Physiological effects of hormones.
- Muscle and animal movement: Electrophysiology and biochemistry of contraction in skeletal, cardiac and visceral muscles.
- Circulatory systems: general plan, electrical and mechanical properties of myogenic and neurogenic hearts. Heart cycle including electrocardiogram, Hemodynamics. Cardiovascular response to extreme conditions like exercise, diving and hemorrhage. Neural control of cardiovascular system.
- Respiratory system: respiratory pigments, transport of gases in blood, regulation of body pH, respiratory response to extreme conditions like hypoxia, diving and exercise. Physiology of respiration (mammals) and neural control of breathing.
- Excretory system: Osmoregulation, osmoregulators Conformers, obligatory exchanges of ions and water. Osmoregulation in water and terrestrial environment. Physiology of mammalian and nonmammalian kidneys.
- Digestive system: Acquisition of Energy: Types of feeding, Digestion (motility and secretions), Metabolism, and absorption, Physiology of gastrointestinal system (mammals) including neural and hormonal regulatory mechanisms.

- Energetics of metabolism expenditure: Body size and metabolic rate, Energetics of locomotion and body rhythms.
- Thermoregulation: Temperature dependence of metabolic rate, determinants of body heat and temperature, thermal biology of ectotherms, heterotherms and endotherms

Suggested Reading

- Animal Physiology by Hill, Wyse & Anderson **2004**
- Animal physiology by Randall Burggren & French **2005**
- Guyton text book of Medical physiology

BIO 307: Biology Laboratory I (2)
BIO 302: Cell Biology (3)

[No. of Lectures: 40-42]

- Introduction to the Cell: The evolution of the cell, From molecules to first cell, From Prokaryotes to eukaryotes, From single cells to multicellular organisms.
- How cells are studied: Microscopy: light microscopy; fluorescence microscopy; Phase contrast microscopy; Electron microscopy, Purification of cells and their parts Cell separation and culture, flow cytometry, Fractionation of cell contents, Tracing cellular molecular with radioactive isotopes and antibodies.
- The Plasma membrane, Membrane structure: The Lipid bilayer, Membrane proteins, membrane carbohydrates, Membrane transport of small molecules, Membrane transport of macromolecules and particles; exocytosis and endocytosis

- The Cell nucleus, Morphology and functional elements of eukaryotic chromosomes,
- Chromosomal DNA and its packaging and organization: The complex global structure of chromosomes and functions implications lampbrush Chromosomes, Polytene chromosomes, heterochromatin, centromeres
- Mitochondria and chloroplast, Structure of the mitochondria and chloroplast, Oxidation of glucose and fatty acids, Electron transport and oxidative phosphorylation, Chloroplast and photosynthesis
- Protein sorting: organelle biogenesis and protein secretion, synthesis and targeting, of mitochondria, chloroplast, peroxisomal proteins, translational modification in the ER. intracellular traffic, vesicular traffic in the secretary pathway, protein sorting in the Golgi, traffic in the endocytic pathway, exocytosis
- The cytoskeleton, the nature of cytoskeleton, Intermediate filaments, Microtubules, Action filaments, Cilia and centrioles, Organization of the cytoskeleton
- Cell growth and division, Overview of the Cell cycle and its control, the molecular mechanisms for regulating mitotic events, Cell cycle control in mammalian cells, checkpoints in cell cycle regulation.
- Neural Cell Biology, Excitable Cell/ Tissue: Neuron and Muscle, neuronal type and properties, basic of transmembrane potential and excitability channels? types? Basic techniques to study Neural Cell Biology

Suggested Reading

- Molecular Biology of the CellAlberts *et al*
- The Cell: A molecular approach Cooper and Hausman
- Molecular Cell BiologyLodish *et al*

BIO 304/602: Molecular Biology (4)

[No. of Lectures: 40-42]

- Macromolecules and Organization: DNA, RNA, proteins: Structure, Conformation, Denaturation, Renaturation
- Chromatin structure, nucleosome
- Genes and genome organisation
- Transposons and retrotransposons
- Processes: DNA Replication mechanism of Prokaryotes/ Eukaryotes
- RNA world and RNA Replication
- Mechanism of transcription in Prokaryotes/ Eukaryotes
- RNA processing: capping, polyadenylation, splicing, editing
- Genetic code and translation
- Regulation: Transcriptional regulation in Prokaryotes/Eukaryotes
- Translational regulation
- Epigenetics
- Gene silencing, RNA interference

Suggested Reading

- Genes IX. Lewin **2008**
- Molecular Biology of the Gene. Watson et. al. 6th edn., **2009**
- Molecular Cell Biology. Lodish et. al.; 6th edn., **2008**
- Molecular Biology of the Cell. Alberts et. al.; 5th edn., **2007**

BIO 306: Plant Physiology (3)

[No. of Lectures: 40-42]

- Water relations**:** Properties of water, Properties of solutions, Cell water potential, soilplantatmosphere continuum.
- Photosynthesis**:** Light absorption, emission, energy transfer, Zscheme of photosynthesis, electron transfer, photophosphorylation, Co2 fixation, C2, C4, CAM plants, Environment and its impact on photosynthesis.
- Respiration**:** ComplexI, complexII**,** complexIII, complexIV, structure and function Oxidative phosphorylation, Cyanideresistant respiration.
- Photomorphogenesis**,** Phytochromes, Crypto Chromes, photomorphogenesis.
- Transport processes in plant**:** Active and passive transport systems, ion channels, driving forces and flow, transport of nutrients across the primary root, transport through sieve element, transport of metabolites from the source to the sink, genetic regulation of transport systems in response to nutrients availability and growth status.
- Mineral nutrition and assimilations of inorganic nutrients**:** Plant microrrhiza association, nitrogen metabolism, sulfur metabolism, phosphate metabolism, calcium metabolism, assimilation of cations, chloride dynamics.
- Lipid metabolism in plants**:** Fatty acid biosynthesis, membrane lipid biosynthesis, lipid desaturation, triacylglycerols, complex lipids, cell wall lipids, alkaloids, ceramides.
- Plant Hormones**:** Introduction and concept, types of growth regulators Auxin: the master growth hormone, *Avena* coleoptiles bioassay, discovery of auxin, distribution in plants, roles, how auxin works? auxin mutants, auxin perception, auxin

binding proteins, signal transduction, auxinresponsive genes/promoters/factors. Model for gene regulation, derepression of early auxin genes, Acid theory, polar auxin transporta chem.iosmotic model, commercial uses of auxin.

- Gibberellins**:** Foolish seedling disease, functions of Gas, location, free vs conjugated Gas, how GA works? signal transduction and mechanism of action of Gas taking amylase as an example, commercial applications.
- Cytokinins**:** location, functions and mechanism of action, commercial applications.
- Ethylene**:** discovery, locations and functions, mutants, mechanism of actions, applications.
- Abscisic acid**:** a natural stress hormone, discovery, location, functions mutantsVP1, ABA and ABI, mechanism of action.
- Programmed cell death**:** hypersensitive response, functions, relevance with diseases, apoptosis, Caspases, Importance of PCD in plant development, role of PCD, model of PCD.

BIO 308: Biology Laboratory II (2)

BIO 401: Immunology (3)

[No. of Lectures: 40-42]

- Introduction to Immune System, organs, cells and molecules
- Mechanisms of barrier to entry of microbes into human body. Natural and adaptive immune responses
- Differentiation of stem cells to different cellular elements in blood, role of cytokines. Introduction to inflammatory reaction, Chemokines, migration of neutrophils to the site of infection, phagocytosis and microbicidal mechanisms.

Parasitic infections and role of Eosinophils Asthma. Basophils, IgE receptor, immediate hypersensitivity.

- TLR receptors and sensing of PAMPs. Signal transduction. Opsonization, Fc Receptors, classification. Prostaglandins and leukotrienes.
- Antibody structure and function. Classification of immunoglobulins, immunoglobulin domains, concept of variability, crosses reactivity. Isotypes, allotypes and Idiotypic markers.
- Idiotypic network Immunoglobulin genes, VJ/VDJ rearrangements and genetic mechanisms responsible for antibody diversity, affinity maturation, allelic exclusion.
- Class switching, receptor and soluble forms of immunoglobulin. Hybridoma and monoclonal antibodies.
- Antibody engineering. B cell differentiation, BCR and preBCR, receptor editing. Complements structure and function. Classical and alternative pathways.
- Concept of Histocompatibility. Genetic organization of H2 and HLA complexes. Class I and class II MHC molecules, structure and function.
- T cell receptors, APCT cell interaction T cell activation, Th1 Th2 cells and cytokines. Intercellular antigen presentation pathways, antigen presentation and MHC restriction.
- T cell differentiation in thymus, aβ and gd T cells. Thymic selection and tolerance to self. Cytotoxic T cells. Super antigens.
- Natural Killer Cells, ADCC, Hybrid resistance, NK cell receptors and NK gene complex, inverse correlation with target MHC expression, missing self hypothesis.

- Cytotoxicity reaction, Apoptosis
- Topics like Immunological techniques, tumor and transplantation Immunology, diseases of relevance to the immune system etc would be discussed in context of the basic immunological mechanisms

Suggested Reading

- Roitt's Essential Immunology
- Immunobiology: The immune system in health and disease by Charles Janeway et al
- Kuby Immunology

BIO 403/603: Microbiology (4)

[No. of Lectures: 40-42]

- History of microbiology: Theory of spontaneous generationExperiments of Pasteur and Tyndall, Koch's Postulates, Isolation of bacteria form natural sample column, Control of microbial growth methods a sterilization.
- Role of bacteria in human welfare: Biological concepts – Immunization (Pasteur experiment Antibiosis), (penicillin story), Griffith's experiment Avery and McCarty's experiment, Experiment with viruses.
- The Microbial cell: General organization of cell, Prokaryotes Eukaryotes and *Archaea*, Cell wall organization on Prokaryotes, Eukaryotes and *Archaea*, Cell surface appendagespilli, locomotion by flagella chemotactic movement, Peptidoglycan synthesisinhibitors in different steps.
- Changing concepts in microbiology taxonomy, earlier systems, molecular taxonomy, Jackard's similarly coefficients.

- Growth and nutrition: Growth kinetics, batch and continuous cultures, nutritional classification of microorganisms, nutritional uptake by microorganisms (C.N.P)
- Metabolic Pathways: Metabolic versatility of microbes, Anaerobic Carbon metabolism: Anaerobic respiration, respiration, Sulphate respiration, Reference to glycolysis, Fermentationdiverse fermentation products, Putrefaction, Methane oxidizing and Methanogenic bacteria, Aerobic Carbon metabolism: TCA cycle alternative metabolic pathways.
- Nitrogen metabolism; Nitrogen Fixation, Assimilatory nitrate reduction, Ammonia assimilation and synthesis of amino acids, Regulation of 'nif'.
- Energy Metabolism: Chemoautotrophs, hydrogen bacteria, phototrophic bacteria/cyanobacteria.
- Microbial Genetics: Modes of genetic exchange in microbes, Transformation, Transduction, Conjugation, evolutionary significance.
- Microbes in Extreme Environment: The basis of extremophiles and their applications, Life of a thermophile (*Thermus, Pyrococcus*).
- Microbes and Agriculture: Symbiotic Nitrogen fixation*Rhizobium, Cyanobacteria (Anabaena, Azolla etc.), Mycorrihiza*, Clinical Microbiology, Survey of disease causing microbes, Mechanisms of Pathogenesis, Antibiotics and their targets, Immune response elicited by microorganisms.
- Industrial Microbiology: Major industrial products from microbes, Beverages, Antibiotics, Secondary metabolites, Recombinant products.

- Environmental Microbiology: Nature of anthropogenic wastes, municipal wastes and xenobiotics, Enrichment cultures, Xenobiotic degrading consortia, Bioremediation.

Suggested Reading

- Microbiology, J.G. Cappuccino, N. Sherman, Pearson Education Publications
- Essential Microbiology, Stuart Hogg, John Wiley and Sons Limited
- Microbiology: A Human Perspective, E.W. Nester, D.G. Anderson, C.E.
- Roberts, N.N. Pearsall , M. T. Nester Mc Graw Hill Higher Education
- Culture of Animal Cells, A Manual of Basic Technique. R. I. Freshney, WileyLiss
- Manual of Environmental Microbiology, C. J. Hurst, R.L.Crawford,
- G.R.Knudsen, M.J. McInerney, L.D. Stetzenbach,, ASM Press.
- Microbiology, L.M. Prescott, J. P. Harley, D.A., Klein , Mc Graw Hill International Edition
- General Microbiology. H.G. Schlegel, Cambridge University Press

BIO 405: Biology Laboratory III (2)

BIO 402/604: Structural Biology (4)

[No. of Lectures: 40-42]

- Brief historical introduction. Basic structure of prokaryotic and eukaryotic cells.
- Chemical composition of living systems - molecular components - chemical structure of proteins, nucleic acids, carbohydrates and lipids

- Forces that hold macromolecules together - the hydrogen bond - the hydrophobic effect and its importance.
- Thermodynamics of biological systems - importance of Gibbs free energy, G - free energy in terms of enthalpy and entropy - dependence of G on temperature and pressure - chemical potential - chemical equilibria - equilibrium coefficient K - effect on K of temperature and van't Hoff equation.
- Detailed analysis of the structures of biological molecules: Amino acids - Structure - Peptide bond - Rigid planar peptide - Cis and Trans configuration - Torsion angles and - Steric hindrance - Hardsphere approximation - contact criteria - Ramachandran (diagram) map - Allowed conformations for a pair of linked peptide units - (map for glycine and alanine residues) - classification of proteins : based on functions - based on structure - globular - fibrous - Levels of structural organization - Types of secondary structure - Helix - Sheet - turns - super secondary and domains.
- Nucleosides and nucleotides - structure of oligonucleotides - Structure of DNA - Watson and Crick model - base pairing and base stacking - Variations in DNA structure - Polymorphism - A, B and Z DNA - Structure of RNA and tRNA.
- Basic principles of modern biophysical and structural methods to study macromolecules from the atomic to cellular levels, including X-ray crystallography, Mass spectrometric technique, NMR spectroscopy, molecular dynamics, cryo-electron microscopy , light microscopy, AFM, single molecule manipulation.

- Introduction to Quantum Chemistry & Molecular Spectroscopy; Introduction to Statistical Mechanics; Statistical thermodynamics, lattice statistics, molecular distribution and correlation functions, the theories of liquids and solutions, phase transitions, cluster theory, and measurement.
- The problem of protein folding. The theoretical and experimental approaches to study protein folding.
- Introduction to Membrane Biophysics. Structure and function of membranes, experimental and theoretical tools for studying biological membranes

BIO 404: Neurobiology (3)

[No. of Lectures: 40-42]

- Introduction to nervous system with emphasis on the structure and function of the brain.
- Structure and function of nerve cells, sensory systems, control of movement and speech, learning and memory, emotion, and diseases of the brain.
- Neurogenetics: This course will explore how principles of genetics can be used as tools to study the complex organization of the nervous system. Examples will be drawn from all relevant model organisms including nematode, fruit fly, mouse, and human.
- Principles of Neurobiology: Topics include structure of ion channels, synaptic transmission, synaptic development, molecular mechanisms of synaptic plasticity, learning and memory and neurological diseases.
- Cognitive Neuroscience: Topics will involve organization of central nervous system,

perception and movement, sensory system, vision and hearing.

- Developmental Neurobiology: Patterning of the nervous system, birth and death of neurons, axon guidance, and the formation, maintenance, and plasticity of synaptic connections. Illustrations will be drawn from systems ranging from worms to flies to humans.

Suggested Reading

- G.M. Shepherd, *Neurobiology* (3rd edition or latest), Oxford university press, Oxford.

BIO 406/606: Cancer Biology (4)

[No. of Lectures: 40-42]

The scientific goal of the Cancer Biology course is to provide the students with knowledge on the fundamental biological mechanisms that underlie the development of cancer. The course will cover several major areas of cancer biology such as cell cycle control, oncogenes and tumor suppressors, DNA damage, tumor microenvironment, chemotherapy and drug resistance.

The ability to understand molecular mechanisms underlying the malignant transformation of cells and to critically evaluate existing literature in cancer biology are two major goals of this course. The lecture materials will provide an overview of each topic whereas discussions of original research articles will be used as a tool for developing critical thinking in the analysis of cancer related research.

Specific Objectives

- To develop a conceptual understanding on the process of cellular transformation resulting from imbalance of cell proliferation and senescence/apoptosis.

- To learn the mechanisms of DNA damage and DNA repair and how their malfunctioning leads to cancer.
- To develop an understanding of molecular mechanisms that allows transformed cells to metastasize by avoiding immune surveillance and activating angiogenesis.
- To facilitate the understanding of how molecular mechanisms of cancer can be utilized for the development of new treatment strategies.

Main Topics

- Cellular transformation
- Oncogenes and tumor suppressors
- DNA damage and mutagenesis
- Genetic instability
- Cell cycle
- Apoptosis
- Oncogenic viruses
- Angiogenesis
- Invasion and Metastasis
- Tumor immunology and immunotherapy
- Chemotherapy
- Metabolism in cancer
- Cancer stem cells

Suggested Reading

- Weinberg R. A. The Biology of Cancer, **2007**
- Mendelson, Howley, Israel, Gray and Thompson. The Molecular Basis of Cancer, **2008**
- Selected review and primary journal articles

BIO 605: Advanced Neuroscience (4)

[No. of Lectures: 40-42]

- Neuropharmacology and Synaptic Transmission
  Synaptic transmission will be studied from a biochemical and pharmacological point of view. We will explore the factors regulating neurotransmitter synthesis, storage, release, receptor interaction, and termination of action. Proposed mechanisms of psychoactive drugs and biochemical theories of psychiatric disorders will be examined.
- Topics in Molecular Mechanisms of Synaptic Development
  Through readings of original manuscripts, the cellular and molecular mechanisms underlying synapse formation and maturation are examined. Topics include: intrinsic versus extrinsic factors regulating neuronal development, cell-cell interactions (neurons and glia), the role of adhesion, neurotrophic and cytoskeletal molecules and synapse development.
- Cells and Circuits of the Nervous System
  Selected topics on the biology of neurons and neuronal networks emphasizing original research literature about the membrane physiology, transmitter function, synaptic plasticity, and neural interactions of different vertebrate and invertibrate central nervous systems.
- Cognitive Neuroscience
  Topics include the major cognitive systems, including perception, decisions, learning and memory, emotion and reward, language, and higher cortical function.
- Neurolgical Disease and Neural Stem Cells. Advances in Learning and Memory.

The course will start with a reading of classic papers in the field of learning and memory. After everyone has acquired this background material, recent papers and trends in this area will be discussed.

Suggested Reading

- M.H. Bear, B. Connors and M. Paradiso, *Neuroscience: Exploring the brains* (3rd edition or latest), Williams and wilkins.
- I.B. Levitan and L.K. Kaczmarek, *the Neuron: Cell and molecular biology* (3rd edition or latest), Oxford university press, Oxford.

BIO 607: Cell Science and Technology (4)

[No. of Lectures: 40-42]

The course describes regulatory processes that involve mechanisms of signal transduction. The emphasis in the course is on the biological regulatory processes and on the understanding of cell react to external influences such as hormones and growth factors. The ability to understand molecular mechanisms of signal transduction in response to extracellular cues and to critically evaluate existing literature in cell signaling major goals of this course. The lecture materials will provide an overview of each topic whereas discussions of original research articles will be used as a tool for developing critical thinking in the analysis of signal transduction-related research.

Specific objectives:

- To understand the conceptual basis of cell signaling in response to extracellular signals.
- To understand how multiple signals bind to their receptors and activate downstream signaling via secondary messangers.

- To understand how phosphorylation and dephosphorylation regulate mutiple signaling pathways
- To understand the role of signaling events in regulating protein-protein interactions, stability and the downstream effector mechanisms.
- Host parasite interaction**:** Recognition and entry processes of different pathogens like bacteria, viruses into animal and plant host cells, alteration of host cell behavior by pathogens, virus-induced cell transformation, pathogen-induced diseases in animals and plants, cell-cell fusion in both normal and abnormal cells.
- Cell signaling: Hormones and their receptors, cell surface receptor, signaling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component signaling systems, bacterial chemotaxis and quorum sensing.

Main Topics:

- Principles of cell communication
- Post-translational modifications of proteins: Phosphorylation, Glycosylation, Ubiquitination and SUMOylation
- G protein-linked receptors
- Protein kinases: PKA signaling pathways (cyclic AMP), PKC Phosphoinosotide signaling (Calcium)
- Receptor tyrosine kinases
- RAS/MAP kinase pathways
- Insulin and the PI-3 kinase pathway
- Intracellular receptors: NO / nuclear receptors
- Adhesion molecules and inside-out/outside-in signaling

- Regulated proteolysis in signaling: Notch, NF-kB, Wnt
- Protein Domains and signal transduction
- Cellular communication: Regulation of hematopoiesis, general principles of cell communication, cell adhesion and roles of different adhesion molecules, gap junctions, extracellular matrix, integrins, neurotransmission and its regulation.

Suggested Reading

- Bastien D. Gomperts, Ijsbrand M. Kramer, Peter E. R. Tatham. Signal Transduction, **2009**
- Harvey Lodish, Arnold Berk, Paul Matsudaira, Chris A. Kaiser, Monty Krieger, Matthew P. Scott, Lawrence Zipursky, and James Darnell. Molecular Cell Biology, **2009**
- Selected review and primary journal articles

BIO 608: Genetics and Disease Biology (4)

[No. of Lectures: 40-42]

- Cell transformation and tumourigenesis Oncogenes: Tumour suppressor genes. DNA repair genes and genetic instability. Epigenetic modifications, telomerase activity, centrosome malfunction.
- Familial cancers: Retinoblastoma, Wilms' tumour, Li-Fraumeni syndrome, colorectal cancer, breast cancer, Genetic predisposition to sporadic cancer.
- Tumour progression: angiogenesis and metastasis. Cancer and environment: physical, chemical and biological carcinogens.
- Immunogenetics: Organization of Ig gene loci. Molecular mechanisms of generation of antibody diversity. Expression of Ig genes. Regulation of Ig

gene transcription. Antibody engineering. Regulation of immune responses, Immunological tolerance. Disorders of Human Immune System.

- Clinical genetics**:** An overview of the genetic basis of syndromes and disorders. Monogenic diseases with well known molecular pathology. Cystic fibrosis, Tay-Sachs syndrome, Marfan syndrome.
- Inborn errors of metabolism and their genetic bases: Phenylketonuria, Maple syrup urine syndrome, Mucopolysaccharidosis, Galactosemia.
- Genome imprinting Syndromes: Prader-Willi & Angelman syndromes, Beckwith-Wiedeman Syndrome. Genomic syndromes: Neurofibromatosis I.
- Neurogenetic disorders: Major regions of human brain and nerve conduction, Charcot-Marie-Tooth syndrome, spinal muscular atrophy, Syndromes due to triplet nucleotide expansion, Alzheimer's disease.
- Muscle genetic disorders: Dystrophies (Duchenne Muscular dytstrophy and Becker Muscular Dystrophy), Myotonias, Myopathies, Genetic disorders of Haemopoitic systems.
- Overview of Blood cell types and haemoglobin: Sickle cell anemia, Thalassemias, Hemophilias.
- Genetic disorders of eye: Colour Blindness, Retinitis pigmentosa, Glaucoma, Cataracts Genetic disorders in skeleton and skin Complex polygenic syndromes: Hyperlipidemia, Atherosclerosis, Diabetes mellitus, Mitochondrial syndromes.
- Genetic experiments to investigate animal behavior. Identifying genes for behavior, Induced mutations, Quantitative trait loci, Synteny

homolog. Investigating the genetics of human behavior.

- Neurogenetics: Study designs: genetic and environmental manipulations, Circadian rhythms, Learning and memory.
- Psychopathology: Schizophrenia, Mood disorders, Anxiety disorders, Disorders of childhood.

BIO 609: Bioinstrumentation (4)

[No. of Lectures: 40-42]

- Histochemical and immunotechniques: Antibody generation, detection of molecules using ELISA, RIA, western blot, immunoprecipitation, flowcytometry and immunofluorescence microscopy, detection of molecules in living cells, *in situ* localization by techniques such as FISH and GISH.
- Separation methods: Electrophoresis, Chromatography and centrifugation.
- Statistical Methods: Measures of central tendency and dispersal; probability distributions (Binomial, Poisson and normal); sampling distribution; difference between parametric and non-parametric statistics; confidence interval; errors; levels of significance; regression and correlation; t-test; analysis of variance; X^2 test;; basic introduction to Muetrovariate statistics, etc.
- Radiolabeling techniques: Properties of different types of radioisotopes normally used in biology, their detection and measurement; incorporation of radioisotopes in biological tissues and cells, molecular imaging of radioactive material, safety guidelines.

- Microscopic techniques: Visulization of cells and subcellular components by light microscopy, resolving powers of different microscopes, microscopy of living cells, scanning and transmission microscopes, different fixation and staining techniques for EM, freeze-etch and freeze-fracture methods for EM, image processing methods in microscopy.
- Electrophysiological methods**:** Single neuron recording, patch-clamp recording, ECG, Brain activity recording, lesion and stimulation of brain, pharmacological testing, PET, MRI, fMRI, CAT.

Suggested Reading

- Lubert Stryer, Biochemistry (5th edition or latest).
- George M. Malacinski and David Freifelder, Essentials of molecular biology
- David M Freifelder, Physical Biochemistry: Applications to Biochemistry and Molecular Biology.

BIO 610: Developmental Biology (4)

[No. of Lectures: 40-42]

- Basic concepts of development: Potency, commitment, specification, induction, competence, determination and differentiation; morphogenetic gradients; cell fate and cell lineages; stem cells; genomic equivalence and the cytoplasmic determinants; imprinting; mutants and transgenics in analysis of development.
- Meiosis, Gametogenesis, fertilization and early development: Production of gametes, cell surface molecules in sperm-egg recognition in animals; embryo sac development and double fertilization in plants; zygote formation, cleavage, blastula

formation, embryonic fields, gastrulation and formation of germ layers in animals; embryogenesis, establishment of symmetry in plants; seed formation and germination.

- Morphogenesis and organogenesis in animals: Cell aggregation and differentiation in *Dictyostelium*; axes and pattern formation in *Drosophila*, amphibia and chick; organogenesis – vulva formation in *Caenorhabditis elegans;* eye lens induction, limb development and regeneration in vertebrates; differentiation of neurons, post embryonic development-larval formation, metamorphosis; environmental regulation of normal development; sex determination.
- Morphogenesis and organogenesis in plants: Organization of shoot and root apical meristem; shoot and root development; leaf development and phyllotaxy; transition to flowering, floral meristems and floral development in *Arabidopsis* and *Antirrhinum.*
- Programmed cell death, aging and senescence**.**

BIO 611: Chromatin Biology

- Chromatin Structure: Nucleosome and chromatin structure.
- Chromatin dynamics: Post-translational histone modifications, Histone variants, Histone acetyltransferase complexes, Histone deacetylase complexes, Histone methyltransferase complexes, Histone demethyltransferases, ATP-dependent chromatin remodeling complexes.
- Role of chromatin in Replication and transcription. Signaling to chromatin.
- DNA repair and chromatin.
- Heterochromatin and gene silencing.

- Chromatin boundaries and insulators.
- In vitro studies of transcription on nucleosome.

Suggested Reading:

- A.P. Wolfe, Chromatin structure and function, Academic press, New York.
- J. Zlatanova and S.H. Leuba (Editors), Chromatin structure and dynamics: State of the art (New comprehensive Biochemistry) Elsevier, Amsterdam.
- B.M. Turner, Chromatin and gene regulation: Molecular mechanisms in epigenetics.
- C.D. Allis, Thomas Jenuwein, Danny Reinberg, Marie-Laure Caparros, Epigenetics, Cold Spring Harbor Laboratory Press.
- Peter B. Becker, Chromatin Protocols (Methods in Molecular Biology), Humana

Departmental Electives/Ph.D. courses

BIO 301/601: Biochemistry

BIO 304/602: Molecular Biology

BIO 403/603: Microbiology

BIO 402/604: Structural Biology

BIO 406/606: Cancer Biology

BIO 605: Advanced Neuroscience

BIO 607: Cell Science and Technology

BIO 608: Genetics and Disease Biology

BIO 609: Bioinstrumentation

BIO 610: Developmental Biology

CHEMISTRY

INORGANIC CHEMISTRY: (3)

CHM 101: General Chemistry I: Inorganic Molecules

[No. of Lectures: 40 – 42]

Atomic Structure, Periodic Table and the Concept of Periodicity: Atomic structure; Vector model of atom and electronic configuration of polyelectronic atoms; atomic structure as the basis for periodicity; Applications of the periodic law. Effective nuclear charge; Slater's rules, screening effect. Size of atoms and ions, ionization energies; electronegativity, electron affinity; periodic properties of elements and periodic trends. Diagonal relationships. Fajan's rules. Relativistic effects: unusual properties of heavier elements.

Chemical Bonding: Lewis theory; Formal charges, resonance and rationalization of structures; VSEPR theory and shapes of molecules. Applications of VSEPR theory in predicting trends in bond lengths and bond angles. Molecular orbital theory of heterodiatomic molecules, concept of HOMO, LUMO and SOMO. The solid state structures, lattice energy and Born-Haber cycle. Perovskite structures and High Tc superconductors (1-2-3 oxides).

Acids and Bases: Various theories of Acids and bases; Brønsted acids and bases. Protonic acids, gas-phase *vs* solution behavior of acids. Concepts of pH, pK_a, pK_b as applied in different chemical structures. Acidity and basicity of oxides. Lewis acidity. 'Hard' and 'Soft' Acids and Bases. Solid acids. Acidity in Zeolites.

Oxidation and Reduction: The central role of transfer of electrons in chemical processes. The importance of splitting of water. Electrode potentials, relation with free energy, Nernst equation. Diagrammatic representation of electrochemical data. Lattimer and Frost Diagrams. Redox chemistry of extraction (Ellingham diagrams). Conversion of chemical energy into electricity. Batteries and modern state of solid state batteries, Fuel cells.

Representative Chemistry of Main Group and Transition Elements: Main group Chemistry: General characteristics of s- and p-block elements [hydrides, oxides, halides], comparative study of second short period elements (B to F) with heavy congeners (Al to Cl). Electron deficient molecules, hyper-valency, concept of multi-centered bonding. General characteristics of Transition elements: Color, magnetism, and variable oxidation states. Transition metal complexes: types of ligands and stereochemistry of complexes. Preliminary idea about crystal field theory[CFT] (splitting of d-orbital energy levels for O_h, T_d and square planar complexes), application of CFT to explain color and magnetism of transition metal complexes. Concept of 18 electron rule among transition metal complexes. Preliminary ideas about relationship of transition metal complexes and metalloenzymes.

Suggested Reading

- *Inorganic Chemistry*, Shriver and Atkins, Fourth Edition, Oxford University Press, **2006**.
- *Concise Inorganic Chemistry*, J. D. Lee, Fifth Edition, Blackwell Publishing, **2006**.
- *Basic Inorganic Chemistry*, F. A. Cotton, G. Wilkinson, P. L. Gaus, Third Edition, John Wiley and Sons Press, **1995**.

CHM 103: Inorganic Chemistry Laboratory (1)

- Estimation of Calcium in Milk Powder through EDTA complexometry.
- Estimation of Iodine in Iodized common salt.
- Determination of Acid neutralizing power of Commercial Antacids.
- Estimation of Phosphoric acid in a Cola by Mo-Blue method.
- Recycling of Aluminum: Preparation of Potash Alum from waste Aluminum
- Blueprinting: Study of Photochemical Reduction of a Ferric salt.
- Preparation of $[Ni(NH_3)_6]^{2+}$ & Ni estimation (Complexometry & Gravimetrically)
- Caffeine Isolation from Tea Leaves.
- An Experiment of Chromatography: Both TLC and Column separations.
- Separation of β-Carotene & Chrophyll from Spinach extract by Paper Chromatography
- Preparation of Ni or Co-Acetylacetonate.
- Preparation of a Metal Complex with a Multidentate Ligand: Preparation of Poly-nuclear Thiourea Complex of Copper (I).
- Preparation of a Polystyrene Film.

CHM 301/601: Symmetry and Group Theory (4)

[No. of Lectures: 40 – 42]

Symmetry and Group Theory

Molecular Symmetry: Symmetry elements and symmetry operations, definition of group and its characteristics, subgroups, classes, similarity transformation. Products of symmetry operations, equivalent atoms and equivalent symmetry elements, chemical equivalence and isomers, enantiotopic hydrogen's and Nuclear Magnetic Resonance Spectroscopy, relations between symmetry

elements and operations, symmetry elements and optical activity, classes of symmetry operations, Conventions regarding coordinate system and axes, point group and classification, degenerate point groups, examples, symmetric and antisymmetric behaviour, Some properties of matrices, representation of groups, reducible and irreducible representations, the great orthogonality theorem, character tables, position vector and base vector as basis for representation, Wave functions as basis for irreducible representations (p- and d-orbitals) direct product, vanishing integral.

Symmetry Adopted Linear Combinations
Projection operators and some examples, e.g. π-orbitals for the cyclopropenyl group etc.

Applications:
Symmetry Aspects of Molecular Orbital Theory
General Principles, symmetry factoring of secular equations, carbocyclic systems, more general cases of LCAO-MO bonding, examples, Huckel Molecular orbital theory systems, e.g., π-systems and conjugated π -systems, benzene and naphthalene systems, determination of coefficients, delocalization energies, resonance energies and aromaticity, electron densities, the bond order (p) and free valence number (F), three centre bonding.
Hybrid Orbitals and Molecular Orbitals
Transformation properties of atomic orbitals, hybridization schemes for !bonding and for π -bonding, hybrid orbitals as LCAO, examples, MO theory for AB_n, molecular orbitals for regular octahedral and tetrahedral molecules (there are some more examples in Cotton's book).

Suggested Reading

- *Chemical Applications of Group Theory*, Cotton, F. A. 3rd edition, Wiley Interscience, New York, **1990**.
- *Symmetry, Orbital and Spectra*, Jaffe, H. H. and Orchin, M. Wiley Interscience, 1971, also Dover Publications **2002**.
- *Symmetry in Chemical Bonding and Structure*, Hatfield, W. F. and Palmer, R. A. C. E. Merrill Publishing Co. USA, **1974**.

CHM 302: Chemistry of Main Group Elements (3)

[No. of Lectures: 40 – 42]

Representative Chemistry of Main-group Elements

- Chemistry of *s*-block elements: Role of Alkali metal ions in biology (complexation and ion transport).
- Chemistry of boron (halides, oxides and oxyacids): boranes, bonding in boranes, topology of boranes, synthesis and reactivity. Carboranes and metallocarboranes, boron nitride.
- Chemistry of Aluminum: Aluminum alkyls, Ziegler Natta Catalysis, Low oxidation state Al compounds.
- Chemistry of Carbon: Graphite, fullerenes, graphene, intercalation compounds and their applications.
- Chemistry of Silicon: Organosilicon Compounds. Silicates and Aluminosilicates, Low-valent Silicon compounds, silylenes and R_3Si^+, Polysilanes.
- Chemistry of Nitrogen: complexes of N_2/NO & NS.
- Chemistry of Phosphorus: oxides, oxyacids, halides, Atomic inversion, Phosphines as ligands, Cone Angle, Berry pseudorotation.

- Chemistry of Oxygen: triplet and singlet oxygen, ligand chemistry of oxygen and ozone (reactivity).
- Chemistry of Sulfur: oxides, oxyacids, halides, S-N compounds $[(SN)_x]$ and polyatomic cations.
- Chemistry of Halogens, Pseudohalogens, interhalogens, halogen cations and Noble Gases-recent trends, CFC's.
- Multiple bonding in heavier main-group elements. Synthesis, Structure and reactivity, Controversies.
- General methods of preparation of main group organometallic compounds and general aspects of their stability.
- Inorganic rings and polymers: Borazines, heterocyclophosphazenes, siloxanes, stannoxanes and the polymers derived from them.
- Nonaqueous solvents: Ammonia, sulfuric acid and sulfur dioxide and superacids.

Topics for Self-Study

- Localized Bonding; VSEPR Theory and prediction of molecular geometry
- Chemical Forces
- Acids and Bases

Suggested Reading

- *Chemistry of the Elements*, 1st Edn. Greenwood, N. N.; and Earnshaw, A. Pergamon, Oxford, **1989**.
- *Inorganic Chemistry-Principles of Structure and Reactivity,* 4th Edn. Huheey J. E.; Keiter, E. A.; and Keiter, R. L. Harper-Collins, NY, **1993.**
- *Modern Inorganic Chemistry,* 2nd Edn. Jolly, W. L. McGraw-Hill, NY, **1991**.

- *Concepts and Models of Inorganic Chemistry*. 3rd Edn. Douglas, B.; McDaniel, D.; and Alexander, J. John Wiley, New York. **1993.**
- *Inorganic Chemistry,* 3rd Edn. Shriver. D. F.; and Atkins. P. W. Oxford University, Oxford, **1999**.

CHM 401: Chemistry of Transition Elements (3)

[No. of Lectures: 40 – 42]

Coordination Chemistry: Coordination number and stereochemistry of coordination complexes (coordination number 2-9). Electronic configurations and states, the ground state and energy levels, free-ion term, Symmetry orbitals and bonding in transition-metal complexes: L-S coupling for d^n states, splitting of one electron levels in an octahedral and tetrahedral environment, Selection rules, spectral transition probability, vibronic coupling, non-centrosymmetric complexes, polarization of allowed transitions, electronic spectra of inorganic complexes and ions, Orgel and Tanabe-Sugano diagrams, Charge-Transfer bands, Jahn-Teller distortion. Applications of CFSE, Stereochemistry of non-rigid and fluxional molecules. Thermodynamic aspects of coordination complexes: nephlauxetic effect, Irving William series, factors affecting ligand field stabilization energies, Molecular Orbital Theory, First row transition elements, heavy transition elements, M-M bonded complexes, C-H activation, agostic interactions, ortho-metallation. Kinetic aspects: reactions and aquation rates, electron transfer reactions. Reaction mechanism in inorganic reactions. Redox reactions, Trans effect.

Organometallic Chemistry: Structure, bonding and reactivity studies of metal carbonyls, nitrosyls, dinitrogen complexes, metal alkyls, carbenes, carbynes and carbides. Metallocenes and related chemistry. Homogeneous and heterogeneous catalysis, oxidative

addition, reductive elimination reactions, organometallic complexes with metal-metal bonds.

Molecular Magnetism: Fundamental equations in molecular magnetism, magnetic susceptibility, orbital quenching and spin-only moment. Magnetic exchange interactions in multinuclear coordination compounds. Low spin-high spin transition, intermediate spin and spin admixed states. Molecule-based magnetic materials.

Inorganic Chemistry of Biological Systems: Essential and trace elements in biological systems, energy sources for life, metalloporphyrins, dioxygen binding, transport, utilization, electron transfer, biochemistry of non-metals.

Chemistry of Lanthanides and Actinides: Electronic configuration, colour and magnetism, properties of lanthanides and actinides; separation of lanthanides (ion-exchange methods), synthesis of trans-Uranic elements, chemistry of uranium compounds, nuclear reactions.

Suggested Reading

- *Inorganic Chemistry-Principles of Structure and Reactivity,* Huheey J. E.; Keiter, E. A.; and Keiter, R. L. 4th Edn., Harper-Collins, NY, **1993**.
- *Modern Inorganic Chemistry,* Jolly, W. L. 2nd Edn., McGraw-Hill, Singapore, **1991**.
- *Concepts and Models of Inorganic Chemistry,* Douglas, B.; McDaniel, D.; and Alexander, J. 3rd Edn., John Wiley, New York. **1993**.
- *Concise Inorganic Chemistry*, J. D. Lee, 5th edition, Blackwell Publishers, **2006**.
- *Advanced Inorganic Chemistry*, Cotton, F. A.; Wilkinson, G.; Murillo, C. A.; Bochmann, M. 6th Edition, Wiley, Singapore, **2004**.

CHM 402/602: Applications of Modern Physical Methods (4) [No. of Lectures: 40 – 42]

UV-Vis & NIR Spectroscopy: Introduction, principles and applications

Infrared Spectroscopy: Introduction, identification of functional groups, hydrogen bonding, metal-ligand vibrations

Mass Spectrometry: Basic concepts, fragmentation and rearrangements (McLafferty rearrangement) of different classes of organic molecules, isotope effects etc.

Nuclear Magnetic Resonance Spectroscopy: Introduction, applications of ^{1}H and ^{13}C NMR spectroscopy including COSY, NOESY techniques in the structural determination of complex organic systems. Application in conformational analysis, Multinuclear NMR of various inorganic and organometallic compounds. Structural elucidation by joint application of IR, NMR and mass spectrometry

Electron Paramagnetic Resonance Spectroscopy: Theory, Analysis of EPR spectra of systems in liquid phase, radicals containing single and multiple set of protons, triplet ground states. Transition metal ions, rare earth ions, ions in solid state. Double resonance techniques: ENDOR in liquid solution, powders and in non-oriented solids. Biological applications: Substrate free radicals, flavins and metal free flavin proteins, photosynthesis, heme proteins, iron-sulfur proteins, spin labels.

Mossbauer Spectroscopy: Physical concepts, spectral line shape, isomer shift, quadrupole splitting, magnetic hyperfine interaction. Interpretation of Mossbauer parameters of ^{57}Fe and ^{119}Sn. Applications: solid-state reactions, thermal decomposition, ligand exchange, electron transfer, isomerism and biological applications.

X-ray Photo-Electron Spectroscopy: Concepts, determination of atomic charges, oxidation numbers, structures of catalyst surface and molecular structures.

CD Spectroscopy: Principles and applications to polypeptides and nucleic acids, induced CD, magnetic circular dichroism.

Fluorescence Spectroscopy: Fluorescence resonance energy transfer and its applications to measurement of distances in molecules.

Electrochemistry: Heterogeneous electron transfer and concept of capacitative and Faradic current. Cyclic voltammogram, instrumentation, CV, DPV and coulometry. Applications of CV in organic and inorganic chemistry.

X-ray Diffraction-Techniques and Instrumentation: Data collection Strategies (Single Crystal and Powder sample), Intensity statistics, Image plate and CCD detectors: Synchrotron radiation usage; Molecular and crystal structure determination (Single Crystal), *Ab-initio* Powder Diffraction, Elements of Neutron and Electron diffraction.

Suggested Reading

- *NMR Spectroscopy – An introduction*, H. Gunther, John Wiley, **1980**.
- *Basic one and two-dimensional NMR spectroscopy*, H. Friebolin, VCH, **1991**.
- *Spectrometric identification of Organic Compounds*, R. M. Silverstein, G. C. Bassler and T. C. Morrill, 5th Ed., John Wiley & Sons, New York, **1991**.
- *Electron Paramagnetic Resonance, Elementary theory and Practical Applications*, Weil, John A, J. R. Bolton, and Wertz, J. E, Wiley-Interscience, New York, **1994.**
- *Structural Methods in Inorganic Chemistry*, E. A. V. Ebsworth, D. W. H. Rankin & S. Cradock, 2nd Ed.**1991**, CRC Press, Boca Raton, Florida.
- *Circular Dichroism: Principles and Applications*, Nakanishi, K., Berova, N., Woody, R. W., Eds.; VCH Publishers, Inc.; New York, **1994**.
- *Principles of Fluorescence Spectroscopy*, J. Lackowicz, Plenum Press, New York **1983**.
- *Electrochemical methods – Fundamentals and applications*, A. J. Baird and L. R. Faulkner, Wiley, **1980**.
- *Applications of Physical Methods to Inorganic and Bioinorganic Chemistry*, R. A. Scott, C. M. Lukehart, Wiley, **2007**.
- *X-Ray Structure Determination-A Practical Guide*, Stout, G. H, Jensen, L. H. 2nd edition, Macmillan, NY, **1968**.
- *The Rietveld Method (IUCr Monograph)*, R. A. Young. Oxford University Press, NY, **1983**.

CHM 603: Advanced Inorganic Chemistry I (4)

[No. of Lectures: 40 – 42]

- Brief discussion on bonding, spectra and magnetism of coordination compounds, Outer-sphere mechanism
- C-H Activation, Agostic interaction, orthometallation and their applications (from literature)
- Fluxional molecules, Dynamic NMR of Carbonyls, nitrosyls, phosphines and Alkene complexes of transition metals
- Photochemistry of transition metal complexes: Photosensitization, photogalvanic cells and photocurrent generation and dye sensitized solar cells.
- Water splitting reaction using coordination compounds.
- Artificial photosynthesis, Nitrogen fixation, Dioxygen binding, and mimics
- Recent applications of transition metal catalysts-Grubbs catalyst, Pd catalysts.
- Carbenes, olefin metathesis.
- Electron transfer reaction and metal-organic frameworks.

Suggested Reading

- *Bioinorganic Photochemistry*, Stochel, G.; Brindell, M.; Macyk, W.; Stasicka, Z.; Szacilowski, K. Wiley, West Sussex, UK, **2009**.
- *Bioinorganic Chemistry*, Lippard, S. J.; Berg, J. M. University Science Books, California, **1994**.
- Discussion on above mentioned topics in relevance to recent literature.

CHM 604: Advanced Inorganic Chemistry I (4)

[No. of Lectures: 40 – 42]

- Concepts, Principles of nontransition metal chemistry: An Overview of bonding Models in Inorganic Chemistry, Chemical Forces, Bent's rule, Application of Molecular orbital theory to polyatomic molecules (localized and delocalized orbitals), Walsh diagrams, Fluxional Molecules, Atomic Inversion, Berry Pseudorotation.

- The role of *p*- and *d*- orbital participation in nonmetals, Periodicity, periodic anomalies of the Nonmetals and post transition metals, multiple bonding in heavier main group elements, charge transfer complexes.
- Comparison of Phosphorus and Silicon: Hypervalency, Stereochemistry, and Reactivity.
- Structurally Diverse π-Cyclopentadienyl Complexes of the Main Group Elements.
- Stable Heavier Carbene Analogues (Silicon, Germanium, Tin and lead): Synthesis, Reactivity and Characterisation.
- Low valent main group compounds (Stabilization).
- Element-Element Addition to Alkynes Catalyzed by the Group 10 Metals (Si-Si, Ge-Ge, B-B, S-S, Se-Se, Ge-Sn, Si-B, Sn-B, S-B, Se-P, Si-S).
- Organometallic Oxides of Main Group and Transition Elements.
- Computational Studies of Transition Metal-Main Group Multiple Bonding.
- Interlocked Macromolecules (Catenanes, Rotaxanes, Pseudorotaxanes).

Suggested Reading

- *Inorganic Chemistry-Principles of Structure and Reactivity,* 4th Edn. Huheey J. E.; Keiter, E. A.; and Keiter, R. L. Harper-Collins, NY, **1993.**
- *Concepts and Models of Inorganic Chemistry,* Douglas, B.; McDaniel, D. Alexander, J. 3rd edition, J. John Wiley, New York. **1993**.
- *Advanced Inorganic Chemistry,* Cotton, F. A.; Wilkinson, G.; Murillo, C. A.; Bochmann, M. 3rd Edition, John Wiley and Sons Press, **1995**.
- Most of the material for this course will be accessed from primary literature viz., Journal articles.

CHM 605: Bioinorganic Chemistry (4)

[No. of Lectures: 40 – 42]

- Mineral Origin of life. Archaeal, Eucarial and Bacterial domain.
- Transition metal ions in biology. Metallobiomolecules. Electron carriers, oxygen carriers, enzymes. Biogeoinorganic chemistry, environment.
- Specific examples: Hemoglobin, Myoglobin, Hemocyanin, Hemrythrin cytochromes, Fe-S proteins, Cytochrome P-450, Nitrophorin, NO-synthase, peroxidase, catalase, Ferritin, cytochrome-C oxidase, cerulplasmin, blue copper proteins, *di-* and *tri*-copper proteins. Other enzymes like, hydrogenase, methane monooxygenase, dioxygenases, dehydratase, nitrogenase, molybdenum containing oxidase and reductase class of enzymes like sulfite oxidase, xanthine oxidase, nitrate reductase, DMSO reductase, tungsten containing formate dehydrogenase and tungsten bearing

hyperthermophilic and thermophilic enzymes. Zn enzymes like carbonic anhydrase, carboxypeptidase, DNA and RNA polymerases, Nickel containing F-430, role of manganese in water splitting.

- Active site analogue reaction models and structural models of these enzymes.
- Environmental chemistry, auto exhaust, arsenic and other heavy metal pollutions.
- Forensic chemistry; inorganic chemistry in medicine, platinum complexes, Mo=S complexes as anti-cancer drugs.
- Biochemistry of Selenium.

Suggested Reading

- *Principles of Bioinorganic Chemistry*, Lippard, S. J.; Berg, J. M. University Science Books, **1994**.
- *Bioinorganic Chemistry*, Bertini, I.; Gray, H. B.; Lippard, S. J.; Valentine, S. J. Viva Books, 1st Edition, **1998**.

CHM 606: Supramolecular Chemistry (4)

[No. of Lectures: 40 – 42]

Concepts: Definition, Development, Classification; Receptors, Coordination and the "Lock and Key" Analogy; Chelate, Conformational and Macrocyclic Effects; Pre-organisation and Complementarity; Thermodynamic and Kinetic Selectivity, Molecular Recognition and Design principles for Molecular Receptors

Hydrogen Bonding and Nature of Supramolecular Interactions: (Ion-Ion, Ion-Dipole, Dipole-Dipole, Cation-π, Anion- π, π-π, van der Waals, Close packing in Solid State and Hydrophobic Effects

Supramolecular Chemistry of Life: Role of Alkali Metal Ions in Biochemical systems; porphyrins and tetrapyrrole macrocycles; Plant Photosynthesis, Transport of oxygen by Hameoglobin, neurotransmitters and hormones, Structure and function of DNA

Ionic Recognition (Cation and Anion Binding Host): Selectivity and Solution Behaviour of Crown Ethers, Lariat Ethers and Podands, Crytands, Spherands; Soft Ligands for Soft Metal Ions, Complexation of Organic Cations, alkalides, electrides, calixarenes, siderophores, biological anion receptors, change from cation to anion hosts (change of Ph), guanidium and organometallic receptors, hydride sponge and related Lewis Acid chelates, Anticrowns and Coordination Interactions

Neutral Host Molecules: Inorganic Solid-State Clathrate compounds, clathrates of organic hosts, intracavity complexes of neutral molecules(Fullerenes and Cyclodextrins): Solution and Solid State Binding

Crystal Engineering: Concepts and Applications, Role of Strong and Weak hydrogen bonds, Cambridge Structural Database, Cocrystal formation

Templates and Self Assembly: Applications to Catenanes, Rotaxanes and Helicates, Role of Positive Cooperativity

Liquid Crystals, Interfaces and Liquid Clathrates: Surfactants and Interfacial Ordering, Design of Liquid Crystalline materials, polymers and crystal displays, properties and discovery of liquid clathrates

Applications: Supramolecular Reactivity, Dendrimers, Homogeneous and Heterogeneous Catalysis, MOF's, Electronic devices (switches, wires and rectifiers) and non-linear optical materials

Suggested Reading

- Most of the material for this course will be accessed from primary research articles.
- Inorganic Chemistry-Principles of Structure and Reactivity. 4th Edn. Huheey J. E.; Keiter, E. A.; and Keiter, R. L. Harper-Collins, NY, **1993**.
- Supramolecular Chemistry. Steed, J. W.; Atwood, J. L. 2nd edition, John Wiley & Sons, UK, **2009**.
- Weak Hydrogen Bond in Structural Chemistry and Biology (IUCr Monograph): Desiraju, G.; Steiner, T. Oxford University Press, NY, **1999**.

CHM 607: Solid State Chemistry and X-ray Diffraction: Principles and Applications (4)

[No. of Lectures: 40 – 42]

Symmetry in the Solid State: Unit Cell, Crystal Systems, Crystal lattices (2D), Bravais Lattices, Miller planes, (directions and multiplicities), d-spacing formula (resolution), Point Symmetry and Point Groups, Space groups, Systematically absent reflections, Asymmetric Unit, crystal density, unit cell contents, and chemical formula.

Elements of X-ray Diffraction: Scattering by an Atom and Crystal, Structure Factor amplitudes (general formula and applications) and Intensities statistics, factors that affect intensities, electron density maps, single crystal structure determination, structure solution and refinement strategy (R-factors) and Rietveld method in Powder diffraction.

General Concepts, Definitions: Structures of Ionic Solids (crystal chemistry), Metals and Alloys, Band Theory in Solids (Metals, Semiconductors, Inorganic Solids), crystal defects, non-stoichiometric compounds, solid solutions, dislocations and stacking faults.

Structure and Bonding in Solids (Crystalline and Amorphous): Factors governing formation of crystal structures, Lattice Energy, Effective nuclear charge, Kapustinskii's equation, Sanderson's Model, Bond Energy and Bond Order calculations, Mooser-Pearson plots, Ionicities, bond valence, bond length, non-bonding electron effects.

Phase Transitions: Buergers's (reconstructive and displacive), Ubbelohde's Classification (continuous and discontinuous), Applications of G-T diagrams, kinetics, critical size and nucleation rate, Avrami Equation, Martensitic, order-disorder transitions.

Ionic Conductivity and Solid Electrolytes: Conduction Mechanisms, Alkali Halides, Lithium, Silver, Oxide and Halide Ion conductors, Conductivity measurements (D.C. and A.C methods), Applications to electrochemical cells, batteries, sensors, and fuel cells.

Structure Property Correlation in Inorganic Materials: Electronic, Electrical, Magnetic, Optical (Luminescence), Dielectric, Ferroelectric and superconductivity.

Preparative Methods: Oxides, nitrides, fluorides and characterization of inorganic solids by different physical (diffraction, microscopic and spectroscopic) techniques.

Suggested Reading

- *Solid State Chemistry and its Applications,* West, A. R. John Wiley & Sons, UK, **1987**.
- *A Basic Course in Crystallography,* Tareen, J. A. K.; Kutty, T. R. N. University Press, India, **2001**.
- *Fundamentals of Crystallography,* Giacavazzo, C. 2nd edition, Oxford University press, NY, **2002**.
- *Basics of Crystallography and Diffraction,* Hammond, C. 2nd edition, Oxford University press, NY, **2003**.
- *Structure and Bonding in Crystalline Materials,* Rohrer, G. S. 1st edition, Cambridge University Press, UK, **2001**.
- *New Directions in Solid State Chemistry,* Rao, C. N. R. ; Gopalakrishnan, J. 2nd edition, Cambridge University Press, UK, **1997**.

CHM 608: Metal-Ligand and Metal-Metal Multiple Bonds (4) [No. of Lectures: 40 – 42]

Ligand Types: Oxo, Sulfido, Nitrido, Imido, Hydroazido($^{2-}$) and related ligands, carbenes, alkylidene, and Alkylidine Ligands.

Electronic Structure: The Nature of Metal-Ligand Multiple Bond; Metal-Oxygen, Metal-Nitrogen, and Metal-Carbon Multiple bonds; Periodic Trends, Ligands comparison, Ligand Reactivity, Role of Metals/ Elements.

Formation of Multiply Bonded Ligands: Cleavage of α-Bond of Precursor, (II) Formation of a Bond to α and β atoms.

IR and NMR Spectroscopy, and Reactivities of Multiply Bonded Ligands: IR Spectra of Terminal Oxo, Nitride, Akylidine, Imido and related complexes, ^{13}C NMR

Spectroscopy. Reactions with Electrophiles and Nucleophiles. Role of Metal-Ligand Multiple Bonds in Catalysis.

Heavier p-Block Elements in multiple Bonds: Synthesis, Characterization, Reactivities of Germanium, Tin, Antimony, Bismuth, Selenium, Tellurium, and Iodine multiple bonded compounds. Zintl ions.

Metal-Metal Multiple Bonds: Formation Criteria for Metal-Metal Bond, Synthetic Methods for Metal-Metal Multiple Bonds Containing Compounds, Bond Length, Spectroscopic and Magnetic Properties, Magic Number, Structure and Bonding, Reactions of Metal-Metal Multi Bonded Complexes.

Suggested Reading

- *Metal-Ligand Multiple Bonds*, Nugent, W. A and Mayer, J. M, First Edition, A Wiley Interscience Publication, **1987**.
- *Organometallics*, Third, Completely Revised and Extended Edition by Christoph Elschenbroich, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, **2006**.
- *Metal Multiple Bonds Between Metal Atoms,* Cotton, F. A.; Murillo, C. A.; Walton, R. A. 3rd Edition, Springer Science Inc. New York, 2**005**.

ORGANIC CHEMISTRY:

CHM 112: General Chemistry II: Organic Molecules (3)

[No. of Lectures: 40– 42]

Structure and Bonding

- Nature of bonding in organic compounds
- Dipole moment, inductive, field effects, polarizability, electrostatic potential surface, etc.
- Resonance, steric inhibition of resonance, hyperconjugation, aromaticity in benzenoid and non-benzenoid compounds (azulenes, tropolones, etc.)

Acidity and Basicity

- Br□nsted/Lewis acids and bases, hard/soft acids and bases, nucleophilicity and basicity
- pK_a,/pK_b, pK_a of organic compounds, structural effects on acidity and basicity, acid and base catalysis

Stereochemistry

- Fischer, Newman, saw-horse, etc., projection formulae
- Conformational analysis of ethane, propane, butane, cyclohexane and monosaccharides
- Stereoisomerism, configuration (*R*, *S*), optical isomerism in compounds with one and two chiral centers, and without an asymmetric atom, nomenclatures such as erythro, threo, α, β, endo, exo epimers, anomers, *E*, *Z*, etc., resolution of racemic compounds
- Biodiscrimination of stereoisomers (aminoacids, thalidomide, DOPA, nicotine, morphine)

Reactive Intermediates

- Introduction to structure, formation, stability and reactions of carbocations, carbanions, free radicals, radical anions, radical cations, arynes, carbenes and nitrenes (in brief)

Addition, Substitution and Elimination Reactions

- Nucleophilic addition to the carbonyl group, electrophilic and radical additions to alkenes, electrophilic and nucleophilic aromatic substitutions, nucleophilic aliphatic substitutions: S_N1, S_N2, S_Ni reactions, neighboring group participation, elimination reactions: E1, E2, and E1cB reactions

Organic Synthesis

- Functional group transformations and their reaction mechanisms
- Molecular rearrangements (basic principles and migratory aptitude): pinacol-pinacolone, Beckmann, Baeyer-Villiger, etc.

Photochemistry

- Basic introduction, vision chemistry, vitamin A and D

Suggested Reading

- Clayden, J., Greeves, N., Warren, S., Wothers, S. *Organic Chemistry*, Oxford University Press, **2001**.
- Hornback, J. M.*Organic Chemistry*, Cengage Learning, **2006**.
- Solomons, T. W. G., Fryhle, C. B.*Organic Chemistry*, John Wiley and Sons, **2007**.

- Morrison, R. M., Boyd, R. N. *Organic Chemistry*, Pearson Education, **2008**.
- Sykes, P. A. *A guide book to mechanism in organic chemistry*, Longman, **2008**.
- Moody, C. J., Whitman, G. H. *Reactive Intermediates,* Oxford University Press, **1992**.

CHM 114: Organic Chemistry Laboratory (1)

- Calibration of melting point apparatus thermometer and determination of melting point.
- Separation of a mixture of organic compounds (carboxylic acid, amine and phenol) by extraction methods
- Hydrolysis of ester: Preparation of salicylic acid from methyl salicylate
- Acetylation of alcohol: Preparation of aspirin from salicylic acid
- Etherification of alcohol: Preparation of 2-ethoxynaphthalene
- Preparation of amide: Synthesis of acetanilide from aniline
- Oxidation of olefin with $KMnO_4$: Preparation of adipic acid from cyclohexene
- Reduction of ketone: Preparation of benzhydrol by $NaBH_4$ reduction of benzophenone
- Aldol reaction: Preparation of dibenzylideneacetone
- Electrophilic aromatic substitution: Nitration of acetanilide
- Nucleophilic substitution reactions: The effect of substrate structure on the reactivity under S_N1 and S_N2 conditions
- Preparation of pyridinium chlorochromate (PCC)
- Preparation of oxime: Synthesis of benzophenone oxime

- Beckmann rearrangement: Preparation of benzanilide from benzophenone oxime

CHM 311: Organic Chemistry I (3)

[No. of Lectures: 40 – 42]

Stereochemistry

- Conformational analysis, conformation of acyclic, cyclic, fused and bridged systems
- Strain in cyclic and acyclic molecules including allylic strain ($A^{1,2}$ and $A^{1,3}$)
- Dynamic stereochemistry: Conformation and reactivity, Curtin-Hammett principle

Rearrangement Reactions

- Electrophilic (Beckmann, Hofmann, Lossen, Curtius, Wolff, Schmidt, Baeyer-Villiger, Pinacol-pinacolone, Wagner-Meerwein etc.), nucleophilic (benzilic acid, Favorskii), and radical rearrangements (Wittig, aza-Wittig)
- Sigmatropic rearrangements (Cope, aza-Cope, Oxy-Cope, Claisen, aza-Claisen, Eschenmoser-Claisen, vinyl cyclopropane-cyclopentene)
- Miscellaneous (Brook, Pummerer)

Oxidations

- Oxidation of alcohols, ketones and aldehydes (transition metal oxidants, hypervalent iodine based, sulphur based, peroxide and peracid, etc.)
- Oxidation of C-C double bonds (Ozone, $KMnO_4$, $Pb(OAc)_4$, Dimethyldioxirane, OsO_4, 2-sulfonyl oxaziridine etc.)
- Oxidation at unfunctionalized carbon

Reductions

- Reduction of carbonyl compounds (hydrogenation, reductions using group III and IV hydride donors, reductive deoxygenation), carbon-carbon multiple bonds (catalytic hydrogenation, diimide reduction) and other selected functional groups
- Dissolving metal reductions

Heterocyclic Chemistry

- General overview and nomenclature of heterocyclic compounds (structure of 3 to 7 membered saturated and 5,6 membered aromatic heterocycles)
- Synthesis and reactions of heterocyclic compounds (in brief)

Introduction to Biomolecules

- Carbohydrates, terpenes, steroids, proteins
- Biosynthesis

Suggested Reading

- Clayden, J., Greeves, N., Warren, S., Wothers, S. *Organic Chemistry*, Oxford University Press, **2001**.
- Eliel, E. L., Wilen, S. H., Doyle, M. P. *Basic Organic Stereochemistry*, John Wiley and Sons, **2001**.
- Smith, M. B. and March, J.*Advanced Organic Chemistry*, Wiley Interscience, **2007**.
- Carey, F. A, Sundberg, R. J.*Advanced Organic Chemistry*, *Part A and B*, Springer, **2007**.
- Anslyn, E. V., Dougherty, D. A. *Modern Physical Organic Chemistry*, University Science Books, **2005**.

- Hornback, J. M.*Organic Chemistry*, Cengage Learning, **2006**.

CHM 313: Organic Chemistry Laboratory (2)

- Preparation of Corey-Bakshi-Shibata (CBS) reagent and enantioselective reduction of a carbonyl compound.
- Preparation of pentacyclic dione via Diels-Alder and photochemical cyclizations.
- Preparation of a Wittig salt and olefination of a carbonyl compound.
- Preparation of Evans chiral auxiliary and its use in asymmetric aldol reaction.
- Preparation of a Grignard reagent and its addition to a carbonyl compound.
- Generation and trapping of benzyne.
- Generation of a carbene: The Reimer-Tiemann reaction.
- The Fischer indole synthesis.
- Sonogashira/Suzuki coupling reaction .
- Olefin metathesis (using Grubbs 1st generation catalyst).

CHM 312: Organic Chemistry II (2)

No. of Lectures: 40 – 42]

C-C Bond Forming Reactions

- *via* enolate, enamine and imine chemistry
- Grignard, cuprate and other conjugate reactions
- Olefination (Wittig, HWE, Julia and Peterson) and cyclopropanation reaction
- Radical reactions
- Other classes (via organo silane, borane and tin based reagents, Baylis-Hillman reaction)

- Pericyclic reactions (cycloaddition, electrocyclic, cheletropic reactions, sigmatropic rearrangements

Enantioselective Reactions

- Principle of enantioselective reactions
- Enantioselective reduction of carbonyl compounds (Corey's oxazaborolidine catalyzed reductions and Noyori's BINAP reduction)
- Enantioselective epoxidation of olefins (Sharpless, Jacobsen, Shi, etc.)

Introduction to Retrosynthesis

- Basic concepts of retrosynthesis, demonstration of its utility with few examples
- Application of above reactions in natural products synthesis (multi step synthesis)

Suggested Reading

- Clayden, J., Greeves, N., Warren, S., Wothers, S. *Organic Chemistry*, Oxford University Press, **2001**.
- Carruthers, W., Coldham, I. *Some Modern Methods of Organic Synthesis*, Cambridge University Press, **2004**.
- Smith, M. B. and March, J.*Advanced Organic Chemistry*, Wiley Interscience, **2007**.
- Carey, F. A., Sundberg, R. J.*Advanced Organic Chemistry*, *Part A and B*, Springer, **2007**.
- Smith, M. B. *Organic Synthesis*, McGraw-Hill, **2001**.
- Warren, S. *Organic Synthesis: The Disconnection Approach*, Wiley, **1983**.

CHM 411/611: Physical Organic Chemistry (4)

[No. of Lectures: 40 – 42]

Chemical Equilibria and Chemical Reactivity

- Thermodynamic and kinetic control of reactions
- Correlation of reactivity with structure, linear free energy relationships, Hammond's postulate, Curtin-Hammett principle, substituent constants and reaction constants

Chemical Kinetics and Isotope Effects

- Various types of catalysis and isotope effects,importance in the elucidation of organic reaction mechanisms

Stereoelectronic Effects in Organic Chemistry

- Role of stereoelectronic effects in the reactivity of acetals, esters, amides and related functional groups
- Reactions at sp^3, sp^2, and sp carbons, Cram, Felkin-Ahn, Zimmerman-Traxler, Houk, Cieplak, exterior frontier orbital extension (EFOE) and cation-complexation models as applied to π-facial stereoselectivity
- Allylic strain ($A^{1,2}$ and $A^{1,3}$) and other strains

Chemistry of Excited States

- Energy and electronic spin states, spectroscopic transitions, Jablonski diagram, photophysical processes, fluorescence and phosphorescence, energy transfer,electron transfer, properties of excited states, electron transfer reactions
- Paterno-Buchi, Norrish type I and II reactions

Pericyclic Reactions

- Conservation of orbital symmetry, Woodward-Hoffmann rules,frontier molecular orbital (FMO) theory
- Orbital overlap effects in cycloadditions, electrocyclizations, sigmatropic rearrangements and chelotropic reactions

Suggested Reading

- Isaacs, N. S. *Physical Organic Chemistry*, Prentice Hall, **1996**.
- Deslongchamps, P. *Stereolectronic Effects in Organic Chemistry*, Elsevier Science, **1983**.
- Carey, F. A., Sundberg, R. J. *Advanced Organic Chemistry*, *Part A and B*, Springer, **2007**.
- Turro, N. J. *Modern Molecular Photochemistry*, University Science Books, **1991**.
- Anslyn, E. V., Dougherty, D. A. *Modern Physical Organic Chemistry*, University Science Books, **2005**.
- Woodward, R. B., Hoffmann, R. *The Conservation of Orbital Symmetry*, Verlag Chemie, **1970**.
- Lehr, R. E., Marchand, A. P. *Orbital Symmetry: A Problem Solving Approach*, Academic Press, **1972**.

CHM 613: Advanced Organic Chemistry I
(Organometallics and Asymmetric Synthesis)

[No. of Lectures: 40 – 42]

Organometallics

- Ligand systems, electron counting and chemical bonding

- Fundamental aspects (ligand substitutions, oxidative addition/reductive elimination, intramolecular insertions/eliminations, nucleophilic/electrophilic addition on coordinated ligands)
- Coupling reactions and their synthetic applications (Mizoroki-Heck, Stille, Negishi, Suzuki-Miyaura, Sonogashira, Kumada andBuchwald-Hartwig reactions)
- Metathesis (mechanisms of various metathesis reactions, Grubbs 1st, 2nd and 3rd generation catalysts, Hoveyda-Grubbs 1st and 2nd generation catalysts, Schrock-Hoveyda chiral olefin metathesis, Furstner's alkyne metathesis, synthetic applications of olefin, enyne, alkyne and cross metathesis)
- Miscellaneous transition metal catalyzed reactions (C-H and C-F bond activation, hydrogenation, carbonylation, oxidation, click chemistry, cyclopropanation, hydrosilylation, etc.)
- Au catalyzed reactions

Asymmetric Synthesis

- Concepts and principles of enantioselective and diastereoselective transformations
- Asymmetric C-C bond forming reactions (aldol, pericyclic and coupling reactions)
- Asymmetric reduction, epoxidation, dihydroxylation and cyclopropanation reactions

Suggested Reading

- Crabtree, R. H. *The organometallic chemistry of the transition metals*, John Wiley, **2005**.
- Hegedus, L. S. *Transition metals in the synthesis of complex organic molecule*, University Science Books, **1999**.

- Grubbs, R. H. (Editor) *Handbook of Metathesis*, (Vol 1-3), Wiley-VCH, **2003**.
- Walsh, P. J., Kozlowski, M. C. *Fundamentals of Asymmetric Catalysis*, University Science Book, **2009**.
- Ojima, I. *Catalysis in Asymmetric Synthesis*, Wiley-VCH, **2004**.
- Carreira, E., Kvaermo, L. *Classics in Stereoselective Synthesis*, Wiley-VCH, **2009**.
- Berkessel, A., Groger, H.*Asymmetric Organocatalysis: From Biomimetic Concepts to Applications in Asymmetric Synthesis,* Wiley-VCH, **2005**.
- Hassner, A. *Advances in Asymmetric Synthesis***,** Vol 3, Elsevier, **1999**.

CHM 612: Advanced Organic Chemistry II (Advanced Organic Synthesis) (4)

[No. of Lectures: 40 – 42]

Key Topics

- Reactions related to synthesis of 3 to 6 membered and higher carbocyclics
- Miscellaneous reactions (tandem/domino, multicomponent, remote functionalization, etc.)
- Philosophy of synthetic design (retrosynthesis, importance of reactivity, relation between functional groups, regio and stereocontrol, use of functional groups as a guide for retrosynthesis)
- Total synthesis of natural products

Suggested Reading

- Clayden, J., Greeves, N., Warren, S., Wothers, S. *Organic Chemistry*, Oxford University Press, **2001**.

- Wyatt, P., Warren, S. *Organic Synthesis: Strategy and Control*, Wiley, **2007**.
- Warren, S. *Organic Synthesis:The Disconnection Approach*, Wiley, **1983**.
- Nicolaou, K. C., Sorensen, E. *Classics in Total Synthesis*, Wiley-VCH, **2008**.
- Nicolaou, K. C., Snyder, S. A. *Classics in Total Synthesis-II*, Wiley-VCH, **2003**.
- Corey, E. J., Cheng, X-M. *The Logic of Chemical Synthesis*, Wiley, **1995**.

CHM 614: Chemical Biology (4)
CHM 615: Frontiers in Organic Chemistry (4)

[No. of Lectures: 40 – 42]

In this course, most recent advances in areas of organic chemistry will be discussed. The emphasis will be to discuss latest research papers and also those published in the last 5 years so as to give an in-depth exposure to the latest advances in organic synthesis.

Suggested Reading

- Current periodicals.

PHYSICAL CHEMISTRY :

CHM 221: General Chemistry III: Chemical Thermodynamics & Kinetics (3)

[No. of Lectures: 40 – 42]

- Zeroth Law of Thermodynamic and concept of Temperature, Definitions of thermodynamics quantities
- First Law of Thermodynamics and its applications
- Concept of Entropy and its Physical Picture

- Second Law of Thermodynamics and its Applications
- Free energy and Standard States
- Conditions of equilibrium and Stability criteria
- Third Law of Thermodynamics
- Phase Equilibrium and Phase Transitions, only to One Component System
- Ideal and Real Gases
- Chemical Equilibrium: Degree of advancement and calculation of equilibrium constant in gas phase. Effect of temperature and pressure on equilibrium constant. Relationship between K_p, K_c and K_x. Solid-Vapour equilibrium. Le Chatelier principle. van't Hoff isotherm, isobar and isochore. Discussion on few systems
- Thermodynamics of Dilute Solutions: Chemical potential, ideal and non-ideal solutions. Raoult's Law and its applications to various systems. Colligative properties: lowering of vapor pressure, ebullioscopy and cryoscopy, osmosis and osmotic pressure along with derivations, van't Hoff Factor (i).
- Thermodynamics of General Phase Equilibrium: Phase rule. Clausius-Clapeyron equation and its applications. Phase diagrams of single component systems (water)
- Reaction Kinetics: Order and Molecularity, determination of order. Kinetics of zero, first and second order reactions. Parallel, reversible and consecutive reactions Concept of steady state hypothesis and some of its applications. Arrhenius equation and activation energy. Theory of unimolecular reactions (Lindemann hypothesis). Collision theory of bimolecular reactions, transition state theory, free energy and entropy of activation. Enzyme kinetics and catalysis.

Suggested Reading

- Atkins, P. W., de Paula, J., *Physical Chemistry*, Ed. 8th, Oxford Press, **2008.**
- Levine, I., *Physical Chemistry*, Ed. 6th, McGraw Hill, **2009**.
- Berry, R. S., Rice, S. A., Ross, J., *Physical Chemistry*, Ed. 2nd, Oxford Press, **2000**.
- Castellan, G. W., *Physical Chemistry*, Ed. 3rd, Narosa Publishing House, **2004**.

CHM 223: Physical Chemistry Laboratory (1)

- Determination of pK_a of polybasic acid (H_3PO_4) with pH meter
- Acidic and basic dissociation constant of glycine and its iso electronic point
- Determination of equivalent conductance at infinite dilution of weak electrolyte (acetic acid)
- Kinetics of saponification of ethyl acetate
- Determination of dissociation constant of acetic acid using conductometry
- Determination of thermal constant of the calorimeter and calculation of the heat of solution and heat of neutralization
- First order kinetics -----acid hydrolysis of methyl acetate taking different concentrations of H^+ ions
- Second order kinetics ------- $K_2S_2O_3$ + KI/H_2O_2
  Or $K_2S_2O_3$ + $KI/KBrO_3$
- Determination of thermodynamic parameters for the two reactions given above
- Potentiometer: (i) Acid base titrations
  (ii) Mixtures of halides versus $AgNO_3$.

CHM 222: Introduction to Spectroscopy (3)

[No. of Lectures: 40 – 42]

Atoms and Molecules

Schrodinger waveequation. Atomic orbitals and probability distribution. Many-electron atoms. Spin and Pauli exclusion principle. Molecular orbitals, bonding in homo- and hetero-nuclear diatomic molecules. Electronegativity and dipole moment. Energy levels of rigid rotor and harmonic oscillator.

Basic Concepts

Nature of electromagnetic radiation, spectral regions, Born-Oppenheimer approximation (qualitative). Width, shape and intensity of the spectral bands, Bear-Lambert law

Microwave Spectroscopy

Moments of inertia of molecules, diatomic molecule as a rigid rotor, rotational spectrum of diatomics and calculations of molecular parameters, diatomic molecule as a non-rigid rotator, hyperfine structure (qualitative picture), rotational spectrum of polyatomic molecules (qualitative), thermal distribution of population among the rotational levels.

Infrared Spectroscopy

Mechanism of IR absorption. Vibrational spectra of diatomic molecules, diatomic molecule as an anharmonic oscillator, population distribution among the various vibrational states, rotation-vibration spectra of diatomic molecules and calculations of molecular parameters. Vibrational modes in polyatomic molecules. Applications of IR spectroscopy in structural eleucidation.

Raman Spectroscopy
Classical and quantum mechanical picture of Raman scattering (qualitative), characteristic parameters of Raman lines, selection rules for Raman scattering, Raman spectra of diatomic molecules and calculation of molecular parameters, vibrational Raman spectra of polyatomic molecule, applications of Raman spectroscopy

Electronic Spectroscopy
Electronic spectra of diatomic molecules, vibrational coarse structure, selection rules, sequence and progression. Franck-Condon principle and spectral intensity distribution. Rotational fine structure in vibronic transitions and its analysis. Isotope effect in molecular spectra.

Nuclear Magnetic Resonance Spectroscopy
Characteristics of nuclear spin states and their energies in presence of external magnetic filed. Transition between nuclear spin states and selection rules, population of nuclear spin states, line shape and line width, chemical shift and shielding constants, display of NMR spectrum, types of spin-spin coupling constants and factors affecting them, concept of magnetically equivalent protons, mechanism of spin-spin interaction (qualitative ideas), applications of NMR spectroscopy.

Basic Ideas of Electron Spin Resonance Spectroscopy
Basic theory, typical spectra and some examples of structure determination.

Basic Ideas of Mass Spectrometry
Basic theory, types of mass spectrometry (qualitative ideas), typical spectra, spectra-structure correlations, few examples on structural determination.

Suggested Reading

- Banwell, N., McCash, E. M., *Fundamentals of Molecular Spectroscopy*, Tata McGraw Hill, **2007**.
- Atkins, P. W., de Paula, J., *Physical Chemistry*, Ed. 8th, Oxford Press, **2008.**
- Engel, T., *Quantum Chemistry and Spectroscopy*, Pearson Education, **2007**.
- Berry, R. S., Rice, S. A., Ross, J., *Physical Chemistry*, Ed. 2nd, Oxford Press, **2000**.

CHM 321/621: Principles of Quantum Chemistry (4)

[No. of Lectures: 40 – 42]

- de Broglie waves and wave-particle duality, Heisenberg's uncertainty principle, wave function and its interpretation, operators, projection and unitary operators, commutator algebra, eigenvalues and eigenvectors, basis sets and matrix representation, change of basis and unitary transformations, parity operator.
- Basic postulates of quantum mechanics, state of a system, measurement and superposition of states, expectation values of dynamical variables, measurement and uncertainty relations, time dependent Schrodinger equation, time-evolution operator, stationary states and time-independent Schrodinger equation, probability current density and conservation of probability, symmetries and conservation laws, virial theorem, quantum-classical mechanics correspondence (Poisson bracket and Ehrenfest theorem).
- Free particle, particle in a box, tunneling effect, harmonic oscillator (both power series and the ladder-operator method), rigid rotor, angular momentum, ladder-operator method for angular momentum.

- Hydrogen atom, atomic orbitals (radial and angular distributions), spin angular momentum in one-electron atoms, spin-orbit interaction, hydrogen atomic term symbols, Zeeman effect.
- Approximation Methods: Variation theorem and its application to helium atom, perturbation theory and its applications (up to Ist order) to helium atom and other simple systems.

Suggested Reading

- Levine, I., *Quantum Chemistry*, Ed. 6th, Pearson Press, **2009**.
- McQuarrie, D. A., *Quantum Chemistry*, Ed. 2nd, University Science Books, **2008**.
- Zettili, N., *Quantum* Mechanics, Ed. 2nd, John Wiley, **2009**.
- Atkins, P. W., Friedman, R. S., *Molecular Quantum Mechanics*, Oxford University Press, **2008**.

CHM 322/622: Statistical Thermodynamics and Rate Theories (4)

[No. of Lectures: 40 – 42]

- Review of Classical Thermodynamics: Laws of thermodynamics and thermodynamic potentials, Legendre transforms and derivative relations, conditions of thermodynamic equilibrium and stability**.**
- Elementary Probability Theory: Definition of Probability, distribution functions and moments, average, variance and binomial distribution for large numbers and central limit theorem, statistical concept of uncertainty.
- Fundamental Principles of Statistical Mechanics: Idea of macroscopic and microscopic states, fundamental postulates of statistical mechanics, statistical mechanical ensembles and its

distribution functions, partition functions, entropy and Boltzmann distribution law relation between partition functions and thermodynamic quantities in different ensembles and fluctuations.

- Ideal Systems: Monatomic, diatomic, and polyatomic gases and calculation of partition functions, thermodynamic quantities of an ideal gas, equipartition theorem, ortho- and para-hydrogen, heat capacities of solids (Einstein and Debye models), chemical equilibrium, indistinguishability, systems of quantum particles and concept of different populations (Bose-Einstein and Fermi-Dirac Statistics), simple examples, classical limits of quantum systems.
- Theories of reaction rates: Collision theory, potential energy surfaces, transition state theory, theories of unimolecular reactions (Hinshelwood, RRK and RRKM treatments), solution Kinetics: factors affecting reaction rates in solution, effect of solvent and ionic strength (primary salt effect) on reaction rates, secondary salt effect.
- Introduction to fast reaction kinetics.

Suggested Reading

- McQuarrie, D. A., *Statistical Mechanics*, University Science Books, **2000**.
- Widom, B., *Statistical Mechanics: A Concise Introduction for Chemists,* Oxford University Press, **2002**.
- Laidler, K. J., *Chemical Kinetics*, Ed. 3rd, Dorling and Kindersley India, **2003**.
- Chandler, D., *Introduction to Modern Statistical Mechanics*, Oxford Press, **1987**.
- Pathria, R. K., *Statistical Mechanics*, Butterworth-Heinemann, Ed. 2nd, **1996.**

CHM 421/623: Theory of Modern Physical Methods

[No. of Lectures: 40 – 42] **(4)**

Intensity and Selection Rules: Theories of absorption and emission, Einstein's coefficient and their relation with transition moment integral, Einstein's spontaneous emission coefficients and lifetime, symmetry properties and selection rules, Franck-Condon principle.

UV-Visible Spectroscopy: Concept of chromophore, electronic transitions in organic compounds, saturated hydrocarbons, multiple double bond (homo-nuclear and hetero-nuclear), benzene system and effect of substitution, effect of solvents, temperature and pressure on the transitions, (some other chromophores).

Infrared Spectroscopy: Introduction to different coordinates (generalized, mass weighted generalized, internal and normal coordinates), simple harmonic motion, anharmonicity, force constant. Selection rules (F and G matrix), applications to organic molecules, Fermi resonance, frequency shifts because of substitutions, isotope effect.

Nuclear Magnetic Resonance Spectroscopy: Nuclear spin and magnetic moment, classical and quantum mechanical description of NMR, origin and theory of chemical shifts; effect of electron density, magnetic anisotropy, ring currents, nuclei other than hydrogen (C-13), isotope effect, paramagnetic species, lanthanide shift reagents, spin-spin coupling, coupling between groups of equivalent nuclei, first order analysis, signs of coupling constants, theory of spin-spin coupling, correlation of coupling constants with other physical properties. Analysis of complex spectra: notation, energy levels and transitions in AX system, quantum mechanical formalism, nuclear spin functions, spin Hamiltonian, two

spin systems without coupling, factoring the secular equation, two coupled spins, selection rules and intensities, AB spectrum, symmetry wave functions and summary of rules for calculating spectra.

Electron Spin Resonance Spectroscopy: Instrumentation, basic principles, typical spectra and spectra-structure relationship, limitations of ESR.

Mass Spectroscopy: Instrumentation, general principles, determination of molecular formula, recognition of molecular ion peaks, typical spectra, spectra-structure correlation, typical applications.

Introduction to Time Resolved Spectroscopy

Suggested Reading

- Jaffe, H. H., Orchin, M., *Theory and Applications of UV Spectroscopy*, John Wiley, **1962**.
- Murrell, J. N., *Theory of Electronic Spectra of Organic Molecules*, John Wiley, **1964**.
- Silverstein, R. M., Bessler, G. C., *Spectrometric Identification of Organic Compounds*, Wiley, **1991**.
- Becker, E. D., *High Resolution NMR: Theory and Application*, Academic Press, **1991**.

CHM 422/624: Chemical Binding (4)

[No. of Lectures: 40 – 42]

- Concept of electron spin, spin angular momentum and their operators, spin eigenfunctions, antisymmetrization operator and many-electron wave functions (Slater determinants), helium atom, Pauli exclusion principle.
- Hartree and Hartree-Fock self-consistent field (SCF) method, Koopmans' theorem, angular momentum in

many-electron atoms, spin-orbit coupling and atomic term symbols, SCF treatment of helium atom.

- Born-Oppenheimer approximation, hydrogen molecular ion, Molecular orbital (MO) treatment of H_2^+ ion, MO treatment of homo and hetero-nuclear diatomic molecules, valence-bond (VB) treatment of diatomic molecules, molecular term symbols, virial theorem for molecules, Hellmann-Feynman theorem.
- Hartree-Fock method for molecules (Roothaan equations) and basis sets, configuration interaction method, Moller-Plesset perturbation theory, coupled-cluster method, density functional theory.
- Huckel MO theory, Pariser-Parr-Pople method, the extended Huckel method, semi-empirical methods.

Suggested Reading

- Levine, I., *Quantum Chemistry*, Ed. 6th, Pearson Press, **2009**.
- McQuarrie, D. A., *Quantum Chemistry*, Ed. 2nd, University Science Books, **2008**.
- Szabo, A., Ostlund, N. S., *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Dover, **1989**.
- Atkins, P. W., Friedman, R. S., *Molecular Quantum Mechanics*, Oxford University Press, **2008**.

CHM 625: Advanced Statistical Mechanics (4)

[No. of Lectures: 40 – 42]

Basic Postulates and Ensembles: Distributions, partition functions and calculation of thermodynamic properties in canonical, microcanonical and grand-canonical ensembles.

Classical Statistical Mechanics: Classical partition function (rotational, vibrational and translational) as the

high temperature limit of its quantum counterpart, microscopic equations of motion, phase space, phase space vectors and Liouville's theorem, the Liouville equation and equilibrium solutions, ergodic theory.

Theory of Imperfect Gases: Cluster expansion for a classical gas, evaluation of cluster integrals, virial expansion of the equation of state, evaluation of the virial coefficients, law of corresponding states.

Theory of the Liquid State: Definition of distribution and correlation functions, radial distribution function, Kirkwood integral equation, potential of mean force and the superposition approximation, YBG hierarchy and the Born-Green equation, Integral equations (Ornstein-Zernicke, Percus-Yevick, hypernetted-chain), density expansions of the pair functions, perturbation theory and the Van der Waals equation.

Nonequilibrium Processes: Brownian motion and Langevin equation, fluctuation-dissipation theorem, classical time correlation functions, Onsager's regression hypothesis, generalized Langevin equation, Brownian motion in a harmonic oscillator heat bath, Fokker-Planck equations, reaction rates (transition state theory, Kramers theory), linear response and Green-Kubo theory, projection operators and the Mori-Zwanzig formalism.

Basic Concepts of Computer Simulations: Introduction to molecular dynamics and Monte Carlo methods.

Critical Phenomena: Critical behaviour of the Van der Waals equation, Ising model, lattice-gas model and binary alloys, broken symmetries, mean-field theories,

Landau-Ginsburg theory, scaling and universality, introduction to renormalization group theory.

Suggested Reading

- Chandler, D., *Introduction to Modern Statistical Mechanics*, Oxford University Press, **1987**.
- McQuarrie, D. A., *Statistical Mechanics*, University Science Books, **2000**.
- Pathria, R. K., *Statistical Mechanics*, Butterworth-Heinemann, Ed. 2nd, **1996**.
- Hansen, J. P., McDonald, I. R., *Theory of Simple Liquids*, Academic Press, Ed. 2nd, **2006**.
- Reichl, L. E., *A Modern Course in Statistical Physics*, John Wiley, Ed. 2nd, **1998**.
- Frenkel, D., Smit, B., *Understanding Molecular Simulation*, Academic Press, Ed. 2nd **2002**.

CHM 626: Physical Photochemistry (4)

[No. of Lectures: 40 – 42]

Introduction to absorption: Lambert-Beer law and its deviation relation between molar extinction coefficient and absorption cross section, Einstein induced absorption coefficient and integrated Einstein induced coefficients, notation of energy levels and electronic transitions

Fluorescence: introduction, Jablonski diagram, kinetic parameters, Einstein's induced and spontaneous emission coefficients, relationship between lifetime and Einstein coefficients (Strickler and Berg' equation) and its limitations, fluorescence quantum yield, Stoke's shift, fluorescence excitation spectrum

Effects of solvents on the fluorescence spectrum: (general effects and specific effects, derivation of the equation), time scales of molecular processes in solutions, applications

Fluorescence quenching: Different mechanism of fluorescence quenching, applications

Radiationless processes: Mechanism for internal and intersystem crossing, effect of temperature of radiationless processes

Phosphorescence: kinetic parameters, origin of triplet state and its formation, different methods of triplet-triplet absorption
Fluorescence Anisotropy and its applications

Resonance Energy Transfer: Different mechanisms of energy transfer (Forster and Dexter mechanism), selection rules for energy transfer, non-vertical energy transfer, Forster Resonance Energy Transfer (FRET), typical examples and choice of dyes

Spectrophotometry and Fluorometry: principles and instrumentation; choice of light sources, monochromators, choice of optical filters and various detector systems used, Concept of Time Correlated Single Photon Counting: Basic principles and instrumentation
Fluorophores and dyes used in spectroscopy: intrinsic and extrinsic fluorophores, protein labeling.

Suggested Reading

- Lakowicz, J. R., *Principles of Fluorescence Spectroscopy*; Ed. 3rd, Plenum Press, **2003**.
- Birks, J. B., *"Photophysics of Aromatic Molecules"*; Wiley-Interscience, **1970**.
- N. J. Turro, N. J., Ramamurthy, V., J. C. Scaiano, J. C., *Principles of Molecular Photochemistry: An Introduction*, University Science Books, California.

- C. A. Parker; "*Photoluminescence of Solutions*"; Elsevier Publishing Company, **1968**.

CHM 627: Lasers in Chemistry and Biology (4)

[No. of Lectures: 40 – 42]

- Fundamentals of Lasers
- Laser-induced fluorescence and multi-photon ionization processes of molecules
- Dynamics of reactions in liquids
- Spectroscopy of single molecule
- Confocal microscopy, fluorescence correlation spectroscopy, fluorescence lifetime imaging, fluorescence lifetime correlation spectroscopy
- Optical and magnetic trapping and manipulation of bio-molecules
- Some applications

Suggested Reading

- Lakowicz, J. R., *Principles of Fluorescence Spectroscopy*, Plenum Press, Ed. 3rd **2003**.
- Silfvast, W. T., *Laser Fundamentals*, Cambridge, Ed. 2nd,
- Demtroder, W. *Laser Spectroscopy: Basic Principles*, Volumes 1 and 2, Springer, Ed. 4th
- Rigler, R., H., Vogel, H., *Single Molecules and Nanotechnology*, Springer.
- Pawley, J. B., Handbook of Biological Confocal Microscopy, Ed. 3rd, Springer,
- Paddock, S. W., *Confocal Microscopy: Methods and Protocol*, Humana Press; Volume 122.

Departmental Electives/Ph.D. Courses:

CHM 603: Advanced Inorganic Chemistry I
CHM 604: Advanced Inorganic Chemistry II
CHM 605: Bioinorganic Chemistry
CHM 606: Supramolecular Chemistry
CHM 607: Solid State Chemistry & X-ray Diffraction
CHM 608: Metal-Ligand & Metal-Metal Multiple Bonds
CHM 612: Advanced Organic Chemistry II (Advanced Organic Synthesis)
CHM 613: Advanced Organic Chemistry I (Organometallics and Asymmetric Synthesis)
CHM 614: Chemical Biology
CHM 615: Frontiers in Organic Chemistry
CHM 625: Advanced Statistical Mechanics
CHM 626: Physical Photochemistry
CHM 627: Lasers in Chemistry and Biology

MATHEMATICS

MTH 101: Calculus of One Variable (3)

[No. of Lectures: 40 – 42]

- Introduction to the real number system, field axioms, order axioms and the completeness axiom
- Sequences and series of numbers, convergence of a sequence, Cauchy's criterion, limit of a sequence, supremum and infimum, absolute and conditional convergence of an infinite series, tests of convergence, examples
- Limits and continuity, definitions, continuity and discontinuity of a function at a point, left and right continuity, examples of continuous and discontinuous functions, intermediate value theorem, boundedness of a continuous function on a closed interval, uniform continuity
- Differentiation, definition and basic properties, Rolle's theorem, mean value theorem, Leibnitz's theorem on successive differentiation, Taylor's theorem
- Integration, Riemann integral viewed as an area, partitions, upper and lower integrals, existence of the Riemann integral, basic properties, fundamental theorem of integral calculus, integration by parts, applications

Recommended Books

- G. B. Thomas and R. L. Finney, *Calculus and Analytic Geometry* (9^{th} edition), Indian student edition, Addison-Wesley, 1998
- T. M. Apostol, *Calculus, Volumes 1 and 2* (2^{nd} edition), Wiley Eastern, 1980
- R. Courant, F. John, *Introduction to calculus and analysis, Vol. 1*, Classics in Mathematics, Springer, 1989

MTH 102: Linear Algebra

[No. of Lectures: 40 – 42]

- Review of complex numbers
- Matrices, matrix operations, special matrices (diagonal, triangular, symmetric, skew-symmetric, orthogonal, hermitian, skew hermitian, unitary, normal), vectors in $\mathbf{R}^n$ and $\mathbf{C}^n$, matrix equation $\mathbf{Ax} = \mathbf{b}$, row-reduced echelon form, row space, column space, and rank of a matrix. Determinants. Systems of linear equations
- Vector space $\mathbf{R}^n$, linear independence and dependence, linear span, linear subspaces, bases and dimensions
- Vector spaces, bases and dimensions, linear transformations, matrix of a linear transformation, rank-nullity theorem
- Inner product spaces, orthonormal bases, Gram-Schmidt orthogonalization, projections
- Eigenvalues and eigenvectors of a linear operator, characteristic polynomial, diagonalizability of a linear operator, eigenvalues of the special matrices stated above, spectral theorem for real symmetric matrices and its application to quadratic forms, positive definite matrices

Recommended books

- T. M. Apostol, *Calculus, Volume 2* (2^{nd} edition), Wiley Eastern, 1980
- H. Anton, *Elementary linear algebra and applications* (8^{th} edition), John Wiley, 1995
- G. Strang, *Linear algebra and its applications* (4^{th} edition), Thomson, 2006
- S. Kumaresan, *Linear algebra - A Geometric Approach*, Prentice Hall of India, 2000

- A. R. Rao and P. Bhimasankaram, *Linear Algebra* (2nd edition), Hindustan Book Agency, 2000
- M. Artin, *Algebra*, Prentice-Hall of India, 1994
- R. Bapat, *Linear Algebra and Linear Models,* Hindustan Book Agency, 1999

MTH 201: Multivariable Calculus and Differential Equations (3) [No. of Lectures: 40 – 42]

- Vectors in $\mathbf{R}^3$, dot product of vectors, length of a vector, orthogonality of vectors, cross product of vectors
- Lines, planes, and quadric surfaces
- Continuity and differentiability of vector-valued functions, tangent vectors
- Functions of two or more variables, limits and continuity, partial derivatives, gradient, directional derivatives, maxima, minima and saddle points, Lagrange multipliers
- Double and triple integrals, change of coordinates, vector fields, line integrals, surface integrals, Green's theorem, Divergence theorem, Stokes' theorem
- First order ordinary differential equations: variables separable, homogeneous, linear and exact equations

Recommended books

- G. B. Thomas and R. L. Finney, *Calculus and Analytic Geometry* (9th edition), Indian student edition, Addison-Wesley, 1998
- T. M. Apostol, *Calculus, Volumes 1 and 2* (2nd edition), Wiley Eastern, 1980
- J. E. Marsden and A. Tromba, *Vector Calculus,* W.h. Freeman & Company, 2004
- R. Courant, F. John, *Introduction to calculus and analysis, Vol. 2*, Classics in Mathematics, Springer, 1989

MTH 202: Complex Variables (3)

[No. of Lectures: 40 – 42]

- Functions of one complex variable, analytic functions, fractional linear transformations
- Cauchy-Riemann equations, harmonic functions
- Power series, term by term differentiation, elementary functions
- Contours and contour integration, Cauchy's theorem, Cauchy's integral formula
- Taylor's series expansion, zeros, singularities, poles, essential singularities, Laurent series
- Residues, residue theorem, evaluation of real integrals and improper integrals
- Conformal mappings

Recommended books

- R. V. Churchill and J. W. Brown, *Complex variables and applications* (7^{th} edition), McGraw-Hill, 2003
- J. M. Howie, *Complex Analysis*, Springer-Verlag, 2004
- T. Gamelin, *Complex Analysis*, UTM, Springer International Edition, 2001
- J. B. Conway, *Functions of One Complex Variable,* Narosa Publishing
- Remmert, *Theory of Complex Functions*, Springer, GTM 122

MTH 301: Groups and Rings (4)

[No. of Lectures: 40 – 42]

- Definition of group, subgroups, normal subgroups, quotient groups
- Basic examples : dihedral, symmetric, alternating, quaternion groups, matrix groups
- Cyclic groups, subgroups of cyclic groups, centralizer, normalizer and stabilizer subgroups

- Simple groups, simplicity of alternating groups
- Homomorphisms and isomorphisms, isomorphism theorems
- Group actions on sets, conjugation, class equation, automorphisms
- Sylow theorems and application on counting groups of a given order
- Direct and semidirect products, groups of small order (if time permits)
- Definition of ring, subrings, ideals, quotient rings
- Basic examples: polynomial rings, matrix rings, group rings, rings of formal power series
- Ring homomorphisms, isomorphisms, Chinese remainder theorem
- Commutative rings, euclidean domains, principal ideal domains, unique factorization domains (if time permits)

Recommended books

- I. N. Herstein, *Topics in Algebra (2nd Edn.),* Wiley, 2006
- T. W. Hungerford, *Algebra*, Springer Verlag, 2005
- M. Artin, *Algebra*, Prentice-Hall of India, 1994
- D. S. Dummit, R. M. Foote, *Abstract Algebra (2nd Edn.),* Wiley
- J. Rotman, *A First Course in Abstract Algebra : With Applications,* Prentice Hall
- J. Rotman, *An Introduction to Theory of Groups,* Springer GTM, 1999
- H. Kurzweil, B. Stellmacher, *The Theory of Finite Groups,* Springer Universitext, 2004

MTH 302: Modules and Fields

[No. of Lectures: 40 – 42]

- Definition of modules and basic examples,

submodules, quotient modules, homomorphisms
- Direct sum of modules, free modules
- Structure theorem for finitely generated modules over a P.I.D., finitely generated abelian groups as examples
- Definition of field and basic examples, field extensions
- Algebraic extensions and algebraic closures
- Classical straightedge and compass constructions
- Splitting fields, separable and inseparable extensions

Recommended Books

- I. N. Herstein, *Topics in Algebra (2nd Edn.),* Wiley, 2006
- T. W. Hungerford, *Algebra*, Springer Verlag, 2005
- M. Artin, *Algebra*, Prentice-Hall of India, 1994
- S. Lang, Algebra (3rd Edn.), Pears
- D. S. Dummit, R. M. Foote, *Abstract Algebra (2nd Edn.),* Wiley

MTH 303: Real Analysis I (4)

No. of Lectures: 40 – 42]

- Real number system, limit superior, limit inferior, supremum principle, completeness, Cantor set
- Sequences and series of functions, uniform convergence and its consequences, space of continuous functions on a closed interval, equicontinuous families, Stone-Weierstrass theorem, Arzela-Ascoli theorem
- Taylor's theorem, power series, radius of convergence, exponential, trigonometric and logarithmic functions
- Monotonic functions, functions of bounded variation, rectifiable curves

- Riemann-Stieltjes integral, properties of Riemann-Stieltjes integral, differentiation of the integral, fundamental theorem of calculus, integration by parts, Gamma function

Recommended books

- T. M. Apostol, *Calculus, Volumes 1 and 2* (2nd edition), Wiley Eastern, 1980
- W. Rudin, *Principles of Mathematical Analysis (3rd Edn.),* McGraw Hill, 1953
- T. M. Apostol, *Mathematical Analysis (2nd Edn.),* Narosa Publishing, 1985
- R. R. Goldberg, *Methods of Real Analysis*
- H. L. Royden, *Real Analysis (3rd Edn.),* Prentice Hall, 2008
- Terrance Tao, *Analysis I & II,* TRIM Series, Hindustan Book Agency

MTH 304: Metric Spaces and Topology (4)

[No. of Lectures: 40 – 42] **Metric Spaces**

- Definition, open sets, closed sets, limit points, convergence, completeness, Baire's theorem, continuity, spaces of continuous functions
- Compactness, sequential compactness, compact metric spaces, compact-open topology, Ascoli's theorem
- Completeness, space filling curve, nowhere differentiable functions

Topology

- Definition and examples of topology, base, subbase, weaker and stronger topology
- Order topology, subspace topology, product and box topology
- Continuity, homeomorphisms, quotient topology

- Compact spaces, examples, Tychonoff's theorem and locally compact spaces, limit point compactness, local compactness
- Connected spaces, components, path components, totally disconnected spaces, locally connected spaces, examples
- Countability axioms, separation axioms, completely regular and normal spaces, Urysohn's lemma, Tietze extension theorem, Urysohn embedding theorem, Stone-Cech compacitification

Recommended Books

- G. F. Simmons, *Introduction to Topology and Modern Analysis*, Tata McGraw Hill, 2008
- J. R. Munkres, *Topology (2nd Edn)*, Dorling Kindersley, 2006

MTH 305: Foundations of Mathematics and Elementary Number Theory (4)

[No. of Lectures: 40 – 42]

- Ordinal and cardinal numbers, countable and uncountable sets
- Propositional and quantified logic
- Statements and Proofs: proof by induction, direct proof, proof by contradiction
- Arithmetic functions: Divisor function, Euler phi function, Moebius function
- Fermat's little theorem, Wilson's theorem, Euler's theorem
- Quadratic reciprocity law
- Primitive roots

Recommended books

- W. Rudin, *Principles of Mathematical Analysis* (3rd Edn.), McGraw Hill, 1953
- D. Burton, *Elementary Number Theory* (6th Edn.), Tata McGraw Hill

- Jones and Jones, *Elementary Number Theory*, Springer, UTM
- David Tall and Ian Stewart, *The Foundations of Mathematics*, Oxford University Press, 1977
- I. Niven, H. S. Zuckerman, *An Introduction to the Theory of Numbers* (5^{th} Edn.), Wiley
- E. Mendelson, *Introduction to Mathematical Logic* (5^{th} Edn.), Chapman & Hall

MTH 306: Ordinary Differential Equations (4)

[No. of Lectures: 40 – 42]

- First-Order Linear equations: exact equations, orthogonal trajectories, homogeneous equations, integrating factors, reduction of order
- Second-order linear equations: equations with constant coefficients, method of undetermined coefficients, variation of parameters, power series solutions, special functions, applications
- Higher-order linear equations
- Some basic concepts of Fourier series
- Quick review of elementary linear algebra, Picard's existence and uniqueness theorem, Sturm comparison theorem
- Systems of first-order equations, homogeneous linear systems with constant coefficients
- Non-linear equations: critical points and stability, Liapunov's direct method, Poincare-Bendixson theory

Recommended Books

- George F. Simmons & Steven Krantz, *Differential equations*, Paperback edition, Tata-McGraw Hill 2009
- G. Birkhoff & G. C. Rota, *Ordinary differential equations*, Paperback edition, John Wiley &Sons, 1989

- E. Coddington & N. Levinson, *Theory of ordinary differential equations*, Paperback edition, Tata-McGrawa Hill, 2008
- W. Hurewicz, *Lectures on ordinary differential equations*, Dover, New York, 1990

MTH 307: Programming and Data Structures (4)

[No. of Lectures: 40 – 42]

- Programming in a structured language such as C
- Data Structures : definition, operations, implementations and applications of basic data structures
- Array, stack, queue, dequeue, priority queue, double linked list, orthogonal list, binary tree & traversal algorithm, threaded binary tree, generalized list
- Binary search, Fibonacci search, binary search tree, height balance tree, heap, B-tree, digital search tree, hashing techniques

Recommended Books

- Donald E. Knuth, *The art of computer programming (*five volumes, 0 - 4*)*, Addison Wesley
- A. V. Aho, J. E. Hopcroft & J. E. Ullman, *Data Structures & Algorithm,* Addison Wesley
- B. W. Kernighan, D. M. Richie, *The C Programming Language*, Prentice Hall

MTH 308: Combinatorics and Graph Theory (4)

[No. of Lectures: 40 – 42]

- **Combinatorics**: Elementary principles of combinatorics (permutations and combinations), binomial coefficients, inclusion-exclusion principle, generating functions, recurrence relation, pigeon-hole principle and Ramsey theory

- **Graph theory**: definition, isomorphisms, degree sequences, connectivity, trees, colourings, Eulerian graphs, directed graphs, network flows

Recommended Books

- R. A. Brualdi, *Introductory Combinatorics* (5th Ed.), Prentice Hall
- F. Harary, *Graph Theory*, Westview Press
- A. Bondy, U. S. R. Murty, *Graph Theory* (1st Ed.), Springer, GTM
- S. M. Cioaba & M. Ram Murty, *A First Course in Graph Theory*, TRIM Series, HBA

MTH 402: Galois Theory (4)

[No. of Lectures: 40 – 42]

- Cyclotomic polynomials, field extensions, Galois extensions
- Fundamental theorem of Galois theory
- Composite and simple extensions, abelian extensions over **Q**
- Galois groups of polynomials, solvability
- Computations of Galois groups over **Q**
- Transcendental extensions, inseparable extensions, infinite Galois groups (if time permits)

Recommended Books

- D. S. Dummit, R. M. Foote, *Abstract Algebra* (2nd Ed.), Wiley
- S. Lang, *Algebra* (3rd Ed.), Pears

MTH 403: Real Analysis II (4)

[No. of Lectures: 40 – 42]

- Vector-valued functions, continuity, linear transformations, differentiation, total derivative, chain rule

- Determinants, Jacobian, implicit function theorem, inverse function theorem, rank theorem
- Partition of unity, Derivatives of higher order
- Riemann intergration in $\mathbf{R}^n$, differentiation of integrals, change of variables, Fubini's theorem
- Exterior algebra, simplices, chains of simplices, Stokes theorem, vector fields, divergence of a vector field, Divergence theorem, closed and exact forms, Poincare lemma

Recommended Books

- David Widder, *Advanced Calculus*, second edition, Dover, 1989
- M. Spivak, *Calculus on manifolds*, fifth edition, Westview Press, 1971
- J. Munkres, *Elementary Differential topology*, Princeton University Press, 1966

MTH 404: Measure and Integration (4)

[No. of Lectures: 40 – 42]

- Topology of the real line, Borel, Hausdorff and Lebesgue measures on the real line, regularity properties, Cantor function
- σ-algebras, measure spaces, measurable functions, integrability, Fatou's lemma, Lebesgue's monotone convergence theorem, Lebesgue's dominated convergence theorem, Egoroff's theorem, Lusin's theorem, the dual space of C(**X**) for a compact, Hausdorff space, **X**
- Comparison with Riemann integral, improper integrals
- Lebesgue's theorem on differentiation of monotonic functions, functions of bounded variation, absolute continuity, differentiation of the integral, Vitali's covering lemma, fundamental theorem of calculus

- Holder's, inequality, Minkowski's inequality, convex functions, Jensen's inequality, $\mathbf{L}^p$ spaces, Riesz-Fischer theorem, dual of $\mathbf{L}^p$ spaces

Recommended Books

- W. Rudin, *Real and Complex Analysis*, third edition. Tata-McGraw Hill, 1987
- H. Royden, *Real Analysis*, third edition, Prentice-Hall of India, 2008
- R. Wheeden, A. Zygmund, *Measure and Integral*, Taylor and Francis, 1977
- J. Kelley, T. Srinivasan, *Measure and Integral*, Volume I, Springer, 1987
- I. Rana, *An Introduction to Measures and Integration*, Narosa Publishing House
- E. Lieb, M. Loss, *Analysis*, Narosa Publishing House

MTH 405: Partial Differential Equations (4)

[No. of Lectures: 40 – 42]

- First-order equations: linear and quasi-linear equations, general first-order equation for a function of two variables, Cauchy problem, envelopes
- Higher-order equations: Cauchy problem, characteristic manifolds, real analytic functions, Cauchy-Kovalevski theorem, Holmgren's uniqueness theorem
- Laplace equation: Green's identity, Fundamental solutions, Poisson's equation, Maximum principle, Dirichlet problem, Green's function, Poisson's formula
- Wave equation: spherical means, Hadamard's method, Duhamel's principle, the general Cauchy problem
- Heat equation: initial-value problem, maximum principle, uniqueness, regularity

Recommended Books

- F. John, *Partial differential equations*, 4th edition, Springer, 1982
- G. B. Folland, *Introduction to Partial differential equations*, 2nd edition, Princeton University Press, 1995
- J. Rauch, *Partial differential equations*, Springer, GTM 128, 1991
- L. Evans, *Partial differential equations,* American Mathematical Society GSM series, 1998

MTH 406: Differential Geometry of Curves and Surfaces [No. of Lectures: 40 – 42] **(4)**

- Curves : curves in space, tangent vector, arc length, curvature, torsion, Frenet formulas
- Surfaces : parametrization, tangent plane, orientability, first fundamental form, area, orientation, Gauss map, second fundamental form, Gauss curvature, ruled and minimal surfaces
- Geodesics, isometries of surfaces, Gauss' Theorema Egregium, Codazzi-Mainardi equations
- Gauss-Bonnet theorem for compact surfaces

Recommended Books

- A. Pressley, *Elementary Differential Geometry*, Springer, Indian reprint, 2004
- Manfredo do Carmo, *Differential Geometry of Curves and Surfaces*, Prentice Hall, 1976
- D. J. Struik, *Lectures on Differential Geometry*, Dover, 1988
- Barrett O'Neill, *Elementary Differential Geometry*, Second edition, Academic Press (Elsevier), 2006

MTH 407: Probability and Statistics (4)

[No. of Lectures: 40 – 42]

- **Probability**: sample space, events, axiomatic development of probability, mutually exclusive events, independent events, conditional probability, Beyes formula, combinatorial probability problems, geometric probability.
- **Statistics**: summarization and tabulation of data, random variables, expectation, variance, moment generating function, marginal and conditional distributions, standard discrete and continuous random variables, elements of estimation and testing of hypotheses.

Recommended Books

- W. Feller, *An Introduction to Probability Theory and Its Applications, Vol. 1,* third edition, Wiley, 1968
- A. Craig, R. Hogg, J. McKean, *Introduction to Mathematical Statistics,* sixth edition, Prentice Hall, 2004
- P. Hoel, S. Port, C. Stone, *Introduction to Probability Theory*, first edition, Brooks Cole, 1972
- V. Rohatgi, A. Saleh, *Introduction to Probability Theory and Statistics,* second edition, Wiley-Interscience, 2000

MTH 408 : Numerical Analysis (4)

[No. of Lectures: 40 – 42]

- Round off errors and computer arithmetic
- Interpolation: Lagrange interpolation, divided differences, Hermite interpolation, splines, numerical differentiation, Richardson extrapolation

- Numerical Integration: trapezoidal, Simpsons, Newton-Cotes, Gauss quadrature, Romberg integration, multiple integrals
- Solution of linear algebraic equations: direct methods, Gauss elimination, pivoting, matrix factorizations
- Iterative methods: matrix norms, Jacobi and Gauss-Siedel methods, relaxation methods
- Computation of eigenvalues and eigenvectors: power method, householders method, QR algorithm
- Numerical solutions of non-linear algebraic equations : bisection, secant and Newton's method, zeroes of polynomials

Recommended Books

- R. L. Burden, D. J. Faires, *Numerical Analysis*
- E. K. Blum, *Numerical Analysis and Computation*, *Theory and Practice,* Dover, 2010
- S. D. Conte, C. De Boor, *Elementary Numerical Analysis*, third edition, McGraw-Hill, 1980
- D. M. Young, R. T. Gregory, *A Survey of Numerical Mathematics*, volumes 1 and 2, Dover, 1988

MTH 409 : Optimization Techniques (4)

[No. of Lectures: 40 – 42]

- Maxima and minima, Lagrange multipliers method, formulation of optimization problems, linear programming, non-linear programming, integer programming problems
- Convex sets, separating hyperplanes theorem, simplex method, two phase simplex method, duality theorem, zero-sum two-person games, branch and bound method of integer linear programming

- Dynamic programming, Bellman's principle of optimality

Recommended Books

- Katta G. Murty, *Linear Programming*, Revised edition, Wiley, 1983
- I. Griva, S. Nash, A. Sofer, *Linear and Non-linear Optimization*, second edition, SIAM, 2008
- M. Bazaraa, H. Sherali, C. Shetty, *Non-linear Programming: Theory and Algorithms*, third edition, Wiley Inter-Science, 2006

Departmental Electives: Programming and Data Structures

1. Combinatorics and Graph Theory
2. Numerical Analysis
3. Optimization Techniques
4. Algebraic Graph Theory
5. Complex Analysis
6. Differential Topology
7. First Course in Algebraic Topology
8. Commutative Algebra
9. Functional Analysis
10. Analytic Number Theory
11. Representation Theory of Finite Groups
12. Fourier Analysis
13. Operator Theory
14. Elementary Introduction to Knot Theory
15. Riemannian Geometry
16. Topological Groups
17. Advanced Linear Algebra
18. Ergodic Theory

19. Harmonic Analysis
20. Lie Groups and Lie Algebra
21. Several Complex Variables
22. Algebraic Number Theory
23. Finite Fields and Applications

PHYSICS

PHY 101: Mechanics (3)

[No. of Lectures: 40-42]

Kinematics: Introduction to coordinate systems, polar coordinate system, velocity and acceleration in polar coordinate system.

Kinetics: Force, Newton's laws of motion, Frames of reference, Momentum, Momentum of system of particles, Conservation laws, Center of mass, Variable mass system, Collision in laboratory and Center of mass system and Scattering.

Relativity: Axioms of relativity, Lorentz transformation, length contraction, time dilation, relativistic mass energy, Doppler effect.

Rigid body motion: Rigid body, Moment of inertia, Rigid body kinematics, Rigid body kinetics, Motion of gyroscope

Non Inertial Frame: Physics in the rotating coordinate system, Fictitious force.

Central force and Motion of planets and satellites

Oscillations and Waves: Small oscillations, damped harmonic oscillation and forced oscillation, Q factor and resonance. Differential equation of one dimensional wave and its solution, reflection and transmission of waves.

Recommended books

- D. Kleppner and R. Kolenkow, *An Introduction to Mechanics*.
- R. P. Feynman, R. B. Leighton and M. Sands, *The Feynman Lecture of Physics* Vol 1.
- C. Kittel, W. D. Knight, M. A. Ruderman, and A. C. Helmholz *Mechanics (Berkeley Physics course) Vol 1.*
- D. Resnick, R. Halliday and K. S. Krane, *Physics, Vol 1, 5th Ed*.
- M. K. Verma, *Introduction to Mechanics*.

PHY 103: General Physics Laboratory I (1)

- Measurement of length and error analysis
- Gyroscope
- Determination of 'g' by bar pendulum
- Pohl's Pendulum
- Determination of 'g' by free fall
- Shear modulus using Tortional pendulum
- Mechanical hysteresis
- Young's modulus
- Moment of Inertia
- Velocity of sound using resonance tube
- Velocity of sound using Kundt's tube
- Spring constant

PHY 102: Electromagnetism and optics

[No. of Lectures: 40-42]

Cylindrical and Spherical coordinate systems: Line, surface and volume elements

Introduction to vector calculus: Gradient, Divergence and curl of Fields, Divergence theorem, Stokes Theorem.

Electrostatics: Coulomb's Law, Gauss's law (integral and differential form) and its applications, Energy of a charge distribution, Laplace's and Poisson's equations (no solutions), The uniqueness theorem (statement only), Conductors, Method of images, Field and Potential due to dipole. Polarization in a dielectric, vectors **D**, **P** and **E**, linear dielectrics, force on dielectrics.

Electric currents: Line, surface and volume currents and current densities, electrical conductivity and Ohm's law, equation of continuity, energy dissipation.

Motion of charged particles in electric and magnetic fields

Magnetostatics: Biot-Savart and Ampere's law, divergence and curl of **B** and the differential form of Ampere's law, vector potential, Magnetic dipoles, magnetization in materials, H, B and M, Dia-, para- and ferro-magnetism, B and H in bar-magnet.

Electrodynamics: Electromagnetic induction, motional emf and Faraday's law, inductance and energy in magnetic field, the displacement current, Maxwell's equations.

Electromagnetic Wave: EM wave in vacuum and dielectrics, Poynting's theorem.

Optics: Light as electromagnetic wave, Spatial and temporal coherence, Interference, color of thin films, Fraunhofer Diffraction by single, double slits and gratings, plane, circular and elliptical polarization of light, dispersion.

Recommended books

- D. J. Griffiths, *Introduction to electrodynamics 3rd Ed*.
- E. M. Purcell, *Electricity and Magnetism (Berkeley Physics course) 2nd Ed.*
- R. P. Feynman, R. B. Leighton and M. Sands, *The Feynman Lecture of Physics Vol 2*.
- E. Hecht, *Optics*, *4th Ed*.
- F. A. Jenkins and H. E. White, Fundamentals of Optics.
- A. K. Ghatak, *Optics*.
- K. K. Sharma, *Optics: principles and applications*.
- G. R. Fowles, *Introducton to Modern Optics*.

PHY 104: General Physics Laboratory II (1)

- Malu's law
- Newton's rings
- Intensity of diffractions due to pin hole diaphragms and circular obstacles
- Magnetic hysteresis loop
- Surface tension by the ring method (Du Nouy method)
- Characteristic curves of a solar cell
- Dielectric constant of different materials
- Charging curve of a capacitor

- Capacitance of metal spheres and of a spherical capacitor
- Magnetic field of paired coils in Helmholtz arrangement
- Electromagnetic induction
- Force of current carrying conductor
- Fresnel's equations

PHY 201: Quantum Physics (3)

[No. of Lectures: 40-42]

Introduction to quantum mechanics

Photoelectric effect, Compton effect, electron diffraction, de Broglie wavelength,

Wave particle duality, Wave function and Born's interpretation, Wave packet, Position and linear momentum, Heisenberg uncertainty principle.

Dynamical variables and corresponding Operators, expectation values, Schrödinger wave equation, stationary states.

Solution of Schrödinger equation in particle in a box, potential barriers and tunneling (eg STM, AFM), Probability current density, bound states of rectangular well potential, simple harmonic oscillator.

Angular momentum, hydrogen atom, spin angular momentum.

Elements of statistical physics

Classical statistics (Arguments leading to Boltzmann Law, $S=k_B \ln\Omega$), Phase space in 2D and 3D (classical and quantum), Identical particles, Bose and Fermi Statistics.

Free electron gas, Fermi energy, Specific heat of metals.

Photon gas, Planck's radiation law and its consequences, Bose Einstein Condensation.

Elements of Solid State Physics
Band theory of solids (basics), Physics of p-n junction.

Elements of Nuclear Physics
Shell Model, Weizsaecker mass formula, Nuclear fusion and fission.

Recommended books

- A. Beiser, *Concept of Modern Physics*.
- H. C. Verma, *Quantum Physics*.
- R. P. Feynman, R. B. Leighton and M. Sands, *The Feynman Lecture of Physics Vol 3*.
- H. S. Mani and G. K. Mehta: *Introduction to Modern Physics*.

PHY 203: General Physics Laboratory III (1)

- e/m ratio using a pair of Helmhotz coils
- Magnetic torque
- Electron diffraction
- Stefan-Boltzmann's law of radiation
- Coils in AC circuit, capacitor in the AC circuit and RLC circuit
- Dispersion and resolving power of prism and grating spectroscope
- Fine structure, one and two electron spectra
- Balmer series/determination of Rydberg's constant
- Atomic spectra of two-electron systems: He, Hg
- Thermal and electrical conductivity of copper and aluminum
- Determination of Planck's constant
- Rotational Spectra of Iodine vapor

PHY 202: Basic Electronics (3)

[No. of Lectures: 40-42]

Network theorem and its applications, Physics of diodes and transistors, terminal characteristics of diodes transistors and FET's, Simple rectifier and amplifier circuits.

Need for signal conditioning and transducers.

Introduction to analog ICs, Op amps: basics, characteristics and applications (filters, waveform generators etc), instrumentation amplifier, Survey of Op-amps.

Functioning and characteristics of commonly used analog ICs such as voltage regulators and power supplies.

Logic Gates ALUs Flip Flop, overview of commonly used CMOS and TTL chips.

Outline of microprocessor functioning, A-D convertors and interfacing.

Signal averaging and sampling theorem and lock-in amplification.

Use of A-D/D-A and I/O cards on a PC.

Recommended books

- P. Horowitz and W. Hill, *The Art of Electronics*.
- R. Gayakwad, *Op-Amps and Linear Integrated Circuits, 4th Ed*.
- P. Malvino and D. P. Leach, *Principle of Digital Electronics*.

- T. L. Floyd, *Electronic Devices*.
- D. R. Choudhary and S. B. Jain, *Linear Integrated Circuits*.
- P. Malvino and J. A. Brown, *Digital computer electronics*.

PHY 204: Electronics Laboratory (1)

- p-n and Zener characterstics.
- Transistor characterstics.
- CE amplifier and frequency response.
- Hartley and Colpitts oscillator.
- Clipper and clamper circuits.
- JFET and MOSFET characterstics.
- Op-amp: Adder/subtracter,Integrator/differentiator.
- Op-amp:Inverting and non-inverting amplifier.
- Astable and Monostable Oscillator using IC555.
- Analog to digital and Digital to analog converter.
- RS,D and JK flip flop.
- Boolean algebra.
- Binary full adder.
- Multiplexer and demultiplexer.
- Thevenin's and Norton theorem

PHY 301: Mathematical Methods I (4)

[No. of Lectures: 40-42]

Vectors analysis in curvilinear coordinates, Tensor analysis (Cartesian only).

Matrices. Eigenvalues and Eigenvectors. Transformation of matrices,
Diagonalization of matrices.

Ordinary differential equations (with constant coeffecients), ODE- singular points. Methods of solutions. Legendre, Bessel, Hermite and Laguire equations and their solutions.

Boundary value problems. Sturm-Liouville theory.

Fourier series expansion and Fourier integrals, their use in some simple problems, Fourier and Laplace transforms.

Partial Differential equations. Green's functions. Solution of Laplace and Poisson's equations, Wave equation.

Recommended books

- B. Arfken and H. J. Weber, *Mathematical Methods for Physicists, 6th Ed*.
- P. K. Chattopadhyay, *Mathematical Physics*.
- M. L. Boas, *Mathematical Methods in Physical Sciences*.
- S. D. Joglekar, *Mathematical Physics: The Basics*.
- A. K. Ghatak, *Mathematical Method of Physics*.
- H. W. Wyld, *Mathematical Methods for Physics*.
- F. B. Hildebrand, *Methods of Applied Mathematics*.
- A. W. Joshi, *Elements of Group Theory for Physicist*.
- S. Hassani, *Mathematical Physics*.
- P. Dennery and A. Krzywicki, *Mathematics for Physicists*.
- J. Mathews and R. L. Walker, *Mathematical Methods of Physics.*

PHY 303: Quantum Mechanics I (4)

[No. of Lectures: 40-42]

Limitations of Classical Physics and need for a quantum theory. Review of Schrodinger description of QM.

The wave equation. Application to one dimensional problems. Two state problems.

Formalization of postulates of Quantum Mechanics. Vector spaces, Operators, Representation theory.

Generalized Uncertainty principle.

Harmonic Oscillator problem. Creation and annihilation operators.

Angular Momentum theory. Eigenstates and Eigenvalues of angular momentum operators. Spin angular momentum. Addition of angular momentum.

Central force problem. Hydrogen atom wavefunctions.

Measurements in Quantum Mechanics, Bell's inequality.

Recommended books

- H. C. Verma, *Quantum Physics*.
- R. P. Feynman, R. B. Leighton and M. Sands, *The Feynman Lecture of Physics Vol 3*.
- J. J. Sakurai, *Modern Quantum Mechanics*.
- B. H. Bransden and C. J. Joachain, *Quantum Mechanics*.
- D. J. Griffiths, *Introduction of Quantum Mechanics*.
- P. A. M. Dirac, The *Principles of Quantum Mechanics*.

- C. Cohen-Tannoudji, *Quantum Mechanics, (Vol I and II)*.
- R. Shankar, *Principles of Quantum Mechanics*.
- A. I. M. Rae, *Quantum Mechanics*.
- E. Merzbacher, *Quantum Mechanics*.
- L. D. Landau and L. M. Lifshitz, *Quantum Mechanics Non-Relativistic Theory*.

PHY 305/601: Classical Mechanics (4)
[No. of Lectures: 40-42]

Review of Newtonian mechanics.

Lagrangian mechanics, generalized coordinates, calculus of variations, constraints, principle of virtual work, Lagrange's equation.

Symmetry principles, Noether theorem,

Central forces, Planetary motions, Collisions, Scattering, Small oscillations, Normal modes, Forced oscillators, Anharmonic oscillators, Perturbation theory.

Rigid body dynamics, Motion of a top.

Hamilton's equations, phase space & phase trajectories, canonical trans-formations, Poisson brackets.

Hamilton- Jacobi theory.

Recommended books
- H. Goldstein, *Classical Mechanics*.
- L. D. Landau and E. M. Lifshitz, *Mechanics*.
- R. G. Takwale and P. S. Puranik, *Introduction to Classical Mechanics*.

- K. C. Gupta, *Classical Mechanics of Particles and Rigid Bodies*.
- N. C. Rana and P. S. Joag, *Classical Mechanics*.
- I. C. Percival and D. Richards, *Introduction to Dynamics*.
- S. H. Strogatz, *Nonlinear Dynamics and Caos*.
- R. Hilborn, *Caos and Nonlinear Dynamics*.

PHY 307: Physics Lab I (3)

- Franck Hertz experiment
- Planck's constant
- Cavendish experiment
- Chua's circuit
- Ferromagnetic Hysteresis
- Atomic spectra of Iodine vapor
- Inelastic electron collision
- Millikan's oil drop experiment
- Viscosity of Newtonian and non-Newtonian liquids
- Microwave based waveguide measurement.

PHY 302: Mathematical Methods II (4)

[No. of Lectures: 40-42]

Complex variables, conformal mapping, residue theorem. Multiple valued function, branch cuts and branch points, saddle point method.

Integral equations. Fredholm and Volterra equations.

Introduction to Groups. Representations, Finite Groups, Permutation Groups.

Continuous Groups, Lie Algebras, Representation of Unitary and rotation group.

Probability and statistics

Numerical methods

Nonlinear differential equations

Recommended books

- B. Arfken and H. J. Weber, *Mathematical Methods for Physicists, 6th Ed*.
- P. K. Chattopadhyay, *Mathematical Physics*.
- M. L. Boas, *Mathematical Methods in Physical Sciences*.
- S. D. Joglekar, *Mathematical Physics: The Basics*.
- A. K. Ghatak, *Mathematical Method of Physics*.
- H. W. Wyld, *Mathematical Methods for Physics*.
- F. B. Hildebrand, *Methods of Applied Mathematics*.
- A. W. Joshi, *Elements of Group Theory for Physicist*.
- S. Hassani, *Mathematical Physics*.
- P. Dennery and A. Krzywicki, *Mathematics for Physicists*.
- J. Mathews and R. L. Walker, *Mathematical Methods of Physics.*

PHY 304: Quantum Mechanics II (4)

[No. of Lectures: 40-42]

Approximation Methods: Time independent and Time dependent perturbation theory, Variational methods and WKB approximation, Fermi-Golden Rule, Applications to matter- radiation (unquantized) interactions.

Scattering by a potential, Partial wave analysis.

Klein-Gordon equation, Dirac equation, plane wave solution, negative energy states, Spin, Magnetic moment.

Parity, Charge Conjugation operations for the Dirac Wave function, Dirac and Majorana particles.

Relativistic invariance of the Dirac equation.

Recommended books

- H. C. Verma, *Quantum Physics*.
- R. P. Feynman, R. B. Leighton and M. Sands, *The Feynman Lecture of Physics Vol 3*.
- J. J. Sakurai, *Modern Quantum Mechanics*.
- B. H. Bransden and C. J. Joachain, *Quantum Mechanics*.
- D. J. Griffiths, *Introduction of Quantum Mechanics*.
- P. A. M. Dirac, The *Principles of Quantum Mechanics*.
- C. Cohen-Tannoudji, *Quantum Mechanics, (Vol I and II)*.
- R. Shankar, *Principles of Quantum Mechanics*.
- A. I. M. Rae, *Quantum Mechanics*.
- E. Merzbacher, *Quantum Mechanics*.
- L. D. Landau and L. M. Lifshitz, *Quantum Mechanics Non-Relativistic Theory*.

PHY 306/602: Statistical Mechanics (4)

No. of Lectures: 40-42]

Review of thermodynamics

Postulates of statistical mechanics.

Phase space, density of states and Liouville's theorem, Ensemble theory (Micro-canonical, Canonical and

Grand-canonical), applications to classical ideal gas and simple numerical problems, Gibbs paradox,

Introduction to Bose-Einstein and Fermi-Dirac statistics, Maxwell-Boltzmann statistics as a classical limit, Qualitative features of degenerate Fermi and Bose gases, electrons in metals, photon gas.

Fluctuations in canonical and grand canonical ensemble.

Phase transition and critical point phenomena, Landau Ginzberg theory. Critical exponents and relations. Scaling and renormalization, Ising model, mean-field theory in zeroth and first approximations, exact solution in one dimension.

Bose Condensation, Density matrix in statistical mechanics.

Recommended books

- F. Reif, *Fundamentals of Statistical and Thermal Physics*.
- R.K. Pathria, *Statistical Mechanics, 2nd Ed.*
- M. Plischke and B. Bergersen, *Equilibrium Statistical Physics*.
- J. K. Bhattacharjee, *Statistical Physics: Equilibrium and Non-Equilibrium Aspects*.
- Kerson Huang, *Statistical Mechanics*.
- S-K. Ma, *Statistical Mechanics*.
- L. D. Landau and E. M. Lifshitz, *Statistical Physics*.
- R. Kubo, M. Toda and N. Hashitsume, *Statistical Physics I and II*.
- S-K. Ma, *Modern Theory of Critical Phenomena*.
- N. Goldenfeld, *Lectures on Phase Transitions and Renormalization Group*.

PHY 308: Physics Lab II (3)

- STM
- AFM
- Raman Spectrometer
- Characteristics of He-Ne laser.
- Fiber optics
- Spectroscopy with fibers [Ocean optics*]
- Michelson Interferometer
- Fabry Parrot Interferometer
- Optical detection of weak source using a lock-in.
- Laser gyroscope

PHY 401/603: Electrodynamics and Special Theory of Relativity (4)

[No. of Lectures: 40-42]

Boundary problems, Formal solution with Green functions, Electric fields in matter, Boundary-Value problems with Dielectrics, Polarizability and Susceptibility, Energy Density in a dielectric, Multipole expansion.

Vector potential, Magnetic fields of a localized current distribution, Magnetic moment, Force and Torque on and energy of a localized current distribution, Boundary conditions on B and H, Boundary value problems in magnetostatics, Multipole expansion.

Maxwell equations, Gauge transformations, Green functions for the wave equation, Poynting's theorem, Tranformation properties of electromagnetic fields and sources under rotations, spatial reflections, and time reversal

Plane electromagnetic waves and wave propagation, polarization, Stokes parameters, Reflection and refraction of electromagnetic waves at a plane interface between dielectrics, wave propagation in conductors and dielectrics, dispersion, complex refractive index, waveguides.

Fields and radiation of a localized oscillating source, Electric dipole fields and radiation, Linear antennas.

Scattering at long wavelengths, Rayleigh scattering

Minkowski space and four vectors, concept of four-velocity, Four acceleration and higher rank tensors, Relativistic formulation of electrodynamics, Maxwell equations in covariant form, Gauge invariance and four-potential, the action principle and electromagnetic energy momentum tensor, Liénard-Weichert potentials, Radiation from an accelerated charge, Larmor formula, bremsstrahlung and synchrotron radiation, multipole radiation, dispersion theory, radiative reaction, radiative damping.

Recommended books

- J. D. Jackson, *Classical Electrodynamics*.
- D. J. Griffiths, *Introduction to Electrodynamics*, 3rd Ed.
- L. D. Landau and E. M. Lifschitz, *Classical Theory of Fields*.
- R. P. Feynman, R. B. Leighton and M. Sands, *The Feynman Lecture of Physics* Vol 2.
- W. K. H. Panofsky and M. Philips. *Classical Electricity and Magnetism*.
- W. R. Smythe, *Static and Dynamic Electricity*.

PHY 403/605: Condensed Matter Physics (4)
[No. of Lectures: 40-42]

Structure of solids, Symmetry, Unit cell, Miller indices, Simple crystal structure,
Diffraction of x-rays, Reciprocal lattice, Laue equations and Bragg's law, Brillouin Zones, Atomic scattering and structure factors, Defects and dislocations.

Bonding in solids, van-der Wall and Repulsive interactions, Lennard Jones potential, Cohesive energy and compressibility, Ionic crystals, Madelung potential, Covalent crystals, Metals, atomic and ionic radii.

Vibrations of one dimensional monoatomic and diatomic chain, Normal modes and Phonons,, Phonon spectrum, Long wavelength of acoustic phonons and elastic constants, specific heat capacity, Density of states, thermal expansion and conductivity.

Free electron theory, Periodic potential, Band theory, Tight binding, Classification of metals, insulators and semiconductors, Cellular and pseudopotential methods, Symmetry of energy bands, Density of state, Fermi surface, de Hass-van Alphen effect, Motion of electron in electric and magnetic fields, Hall Effect, Quantum Hall Effect, Magnetoresistance, Superconductivity, Meissner effect.

Dia-, Para-and Ferromagnetism, origin of magnetism, Langevin's theory of paramagnetism, Weiss Molecular theory, Ferromagnetic ordering, spin waves, magnons, ferromagnetic domains.

Recommended books

- L. V. Azaroff, *Introduction to Solids*.
- C. Kittel, *Introduction to Solids State Physics*.
- N. W. Ashcroft and N. D. Mermin, *Solids State Physics*.
- A. J. Decker, *Solids State Physics*.
- O. Madelung, *Introduction to Solid State Theory*.
- P. M. Chaikin and T. C. Lubensky, *Principles of Condensed Matter Physics*.
- H. Ibach and H. Lutz, *Solid State Physics*.
- J. Weertman and J. R. Weertman, *Elementary Dislocation Theory.*
- M. J. Buerge, *Crystal Structure Analysis*.
- J. Callaway, *Quantum Theory of solid State*.

PHY 405: Condensed Matter Lab (3)

- Lattice dynamics
- Abbe refractometer
- Curie Temperature
- Dielectric constant
- Thermal expansion of quartz crystal
- Hall effect
- Thin film preparation and thickness measurement
- Raman effect
- Interfacing a multimeter through GPIB
- X-ray diffraction
- Electro-optic effect (Kerr effect)
- Fabry-Perot and Mach-Zender Interferometer
- Fiber Optics (Estimation of numerical aperture, bending loss)
- Holography.

PHY 402: Atomic and Molecular Physics (4)

[No. of Lectures: 40-42]

Brief review of hydrogen atom and periodic table,

Significance of four quantum numbers and concept of atomic orbitals. One valence electron atom: Orbital magnetic dipole moment, Orbital, spin and total angular momenta, Larmor precession, Spin-orbit interaction and fine structure, Intensity of spectral lines, General selection rules. Stark, Zeeman and Paschenbeck effects.

Two valence electron atoms: LS and JJ coupling schemes and resulting spectra.

Many electron atom, approximation methods, Hartree-Fock.

Width and shape of spectral lines, Hyperfine structure of lines.

Principal of ESR with experimental setup, chemical shift.

Hydrogen molecule, concept of valence and bonding.

Molecular Orbital and Electronic configuration of Diatomic molecules: H_2, C_2, O_2, NO and CN), Vibrational structure and vibrational analysis, Frank Condon Principle, Dissociation Energy, Rotational, Raman spectra and influence of nuclear spin.

Recommended books

- P. W. Atkins and R. S. Friedman, *Molecular Quantum Mechanics 3rd Ed*.
- W. Demtroder, *Atoms, Molecules and Photons*.
- G. W. Woodgate, *Elementary Atomic Structure*.

- H. S. Friedrich, *Theoretical Atomic Physics*.
- R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*.
- H. E. White, *Introduction to Atomic Spectra*.
- B. H. Bransden and C. J. Joachain, *Physics of Atoms and Molecules*.
- H. G. Kuhn, *Atomic Spectra*.
- F. A. Cotton, *Chemical Applications of Group Theory*.
- C. N. Banwell, *Fundamentals of Molecular Spectroscopy*.
- G. M. Barrow, *Introduction to Molecular Spectroscopy*.
- J. M. Hollas, *Modern Spectroscopy*.
- C. A. Coulson, *Valence*.

PHY 404: Nuclear and Particle Physics (4)

[No. of Lectures: 40-42]

Properties of nucleon-nucleon interaction, General forms of N-N potential, Description of low energy neutron-proton scattering to show the spin dependence of nuclear force, Ground state properties of deuteron, Simple consideration of deuteron using central potential (square well).

Nucleon emission, separation energy, Alpha decay and its energy spectrum, Q-value, Gamow's theory of alpha decay (no derivation), Beta decay and its energy spectrum (for example, ^{137}Cs), Need for neutrinos, Q-value for beta decay, Gamma decay, Selection rules for gamma transitions (no derivation).

Outline of interaction of charged particles and of Gamma-rays with matter.

Detectors: Gas Filled counters (ionization Chamber), Scintillation counter, Spark Chambers, Cerenkov detectors.

Accelerators: Ion Sources, Synchrotron, Introduction of Modern Colliders (LHC and RHIC), Storage Ring

Discussion of Direct and Compound nuclear reaction mechanisms, expressions for scattering and reaction cross-sections in terms of partial wave amplitudes. Resonances, Discussions and Applications of Breit-Wigner single-level formula, compound nucleus theory.

Electromagnetic interactions in nuclei, Multipole transitions in nuclei, Parity and angular momentum selection rules, Internal conversion, Fermi theory of beta-decay, Curie plots, Comparative half life. Allowed and forbidden transitions, Detection and properties of neutrino.

Deuteron problem. Tensor force, S and D states. Neutron-Proton and proton-proton scattering, Effective range theory, Spin-dependence of nuclear forces, Charge independence and charge symmetry of nuclear forces, Isospin formalism.

Basic interactions in nature, Elementary particles, Quantum numbers and conservation laws, Concept of isospin, Quarks and colors, Quark model, Eightfold way, Mesons and Baryons, Bound states and resonance states.

Recommended books

- S. S. M. Wong, *Introductory Nuclear Physics*.
- V. Devanathan, *Nuclear Physics*.
- B. L. Cohen, *Concepts of Nuclear Physics*.
- B. B. Srivastava, *Fundamentals of Nuclear Physics*.
- H. A. Enge, *Introduction to Nuclear Physics*.

PHY 406: Nuclear Lab (3)

- Half life and radioactive equilibrium
- Balmer series/Determination of Rydberg's constant
- GM counter.
- Gamma - Ray Spectroscopy Using NaI (Tl) detector.
- Alpha Spectroscopy with Surface Barrier Detector.
- Determination of the range and energy of alpha partcles using spark counter.
- Study of gamma ray absorption process.
- X-Ray Fluorescence.
- Neutron Activation Analysis Measurement of the Thermal Neutron Flux.
- To Study the Solid State Nuclear Track Detector.
- Fission Fragment Energy Loss Measurements from Cf^{252}.
- Gamma - Gamma Coicidence studies.
- Compton Scattering: Energy Determination.
- Compton Scattering: Cross-Section Determination.
- Determination of energy of mu-mesons in pi-decay using Nuclear Emulsion Technique.
- Identification of particles by visual range in Nuclear Emulsion.
- Study of Rutherford Scattering.

List of elective courses to be offered from physics department:

- Magnetism and Superconductivity
- Advanced Condensed Matter Physics
- Nonequilibrium Statistical Mechanics
- Ferroelectricity and Ferroelectric Devices
- Semiconductors and Optoelectric devices
- Photonic Devices
- Nonlinear Optics and Laser Theory
- Experimental Techniques
- Particle Physics
- Quantum Field Theory (2 Semester Course)
- Thin Film Technology
- Field Theory in Condensed Matter
- Nanoscience and Nanotechnology
- Astrophysics
- Plasma Physics
- Quantum Optics
- GTR and Cosmology (2 Semester Course)
- Computational Physics and Numerical Analysis
- Spintronics
- Crystallographic computation and structural analysis.

EARTH AND ENVIRONMENTAL SCIENCE

EES 101: ENVIRONMENTAL SCIENCE (3)

[No. of Lectures: 40-42]

Physical environment: Lithosphere
Earth's internal structure**,** Plate tectonics, Rocks and minerals, Soil - its formation, composition and classification

Physical environment: Hydrosphere
Hydrologic cycle, Freshwater resources, Oceans – their composition and stratification

Physical environment: Atmosphere
Structure and composition of the atmosphere, Earth's radiation budget, Weather and climate, Global atmospheric circulation

Natural resources: Use, over-exploitation and conservation
Mineral, water, land, forest resources, Dams-benefits and problems, Rain water harvesting, Wasteland reclamation
Energy resources: Renewable and non renewable energy sources, use of alternate energy sources.

Atmospheric pollution
Sources of each pollutant, Smog, Acid rain

Consequence of atmospheric pollution: Global climate change
Greenhouse gases, Sources of greenhouse gases, Consequences of global warming

Consequence of atmospheric pollution: Ozone layer depletion
Formation and shielding effect of the ozone, Ozone depleting gases, ozone destruction and its effects

Reduction & control of air pollution
Methods of control, International treaty to reduce pollution. E.g. Kyoto Protocol, Montreal Protocol

Water pollution
Types, general properties and dynamics of water pollutants, Thermal pollution, Acid drainage, mines and acid rain, Sewage treatment

Solid waste and its management
Types and sources of solid waste, Control of solid waste, Methods of solid waste treatment

Soil degradation
Soil erosion & Desertification, Major impacts of soil degradation, Soil conservation techniques

Radioactive and noise pollution
Nuclear fuel cycle, Nuclear power concerns, exposure to radiation
Noise: measurement, classification and hazards

Remote sensing and GIS
Basic principles and applications

Ecological principles and concepts
concept of species, populations, communities and ecosystem
Dynamics of biological populations, Interactions between species, Food chains and food webs, Energy flow in ecosystems

Conservation biology
Definition, levels and measurement of biological diversity, Threats to biodiversity, Conservation of biological diversity

Suggested textbooks

- Cunningham, W.P., Cunningham, M.A. & Saigo, B. *Environmental Science, a Global Concern*. McGraw-Hill (Boston)
- Nebel, BJ & Wright, R. *Environmental Science: Toward a Sustainable Future*. Prentice-Hall.
- E. D. Enger & B. E. Smith. Environmental Science – A study of Inter relationships. McGraw-Hill (Boston)

EES 202/602: Atmospheric Sciences (3)
[No. of Lectures 40-42]

Introduction: Significance of studying atmospheric sciences in the regional and global contexts, prediction of weather and climate change, identification and remediation of environmental threats. Atmospheric sciences as an inter-disciplinary area of study, evolution and progress in the discipline. Recent trends and emerging frontiers

Earth's atmosphere: Sun and its origin, spectrum of radiation of the sun and earth, evolution of the earth and its atmosphere. Atmospheric elements and compounds, chemical structure and reactivity, lifetime of chemicals. Structure and composition of the atmosphere, Global circulation patterns

Atmospheric radiation: Quantitative description of radiation, blackbody radiation, Planck function, local thermodynamic equilibrium, absorption and emission by

atmospheric gases, scattering by air molecules and particles, absorption by particles, Beer-Lambert law

Atmospheric thermodynamics: Basic definitions, Absolute temperature, Boyle's law, Dalton's law. Hydrostatic balance, First law of thermodynamics. Air parcel concept. Moisture in the atmosphere, measure and description of moist air, isobaric cooling, saturated adiabatic lapse rate.
Vertical mixing, vertical stability in the atmosphere, stability analysis and conditions

Tropospheric chemistry: Composition of tropospheric air, sources, transport, and sinks of important trace gases (O3, CO, OH , NOx, and VOCs). Tropospheric aerosol, sources, composition, -size distribution and concentrations, transport, residence times, and sinks. Urban pollution episodes, smog formation

Stratospheric chemistry: Overview, Chapman mechanism for ozone formation and destruction,
NOx cycle, and halogen cycles. Ozone hole. Stratospheric aerosols

Suggested books:

- Atmospheric Science: An introductory survey (2nd edition), John M. Wallace and Peter V. Hobbs, Academic Press (2006).
- Atmospheric Chemistry and Physics: From Air Pollution to Climate Change (2nd edition), John
- Seinfeld, Sypros N. Pandis, Wiley-Interscience (2006)
- An Introduction to Atmospheric Thermodynamics (2nd edition), Anastasios A. Tsonis, Cambridge University Press (2007)

EES 301/603: Science of Sustainability: Managing Earth Resources (4)

[No. of Lectures 40-42]

Introduction: Introduction to the concept of sustainable development/industrial ecology, historical development of industrial ecology, linking industrial activity with earth resources.

Analogy between ecosystems and industrial systems: Biological and industrial organism/systems, similarities and differences, concept of metabolism: biological and industrial organisms, industry-earth interactions, utility of the ecological approach, and discussion of practical symbiotic cases from a sustainability perspective.

Materials and the environment: Adopting a systems perspective, defining system boundaries, life cycle of materials, definitions and terminology, assessing material and energy flows, eco-efficiency, pollution prevention principles, cradle to grave approach - waste and recycling, resource dissipation, and cradle to cradle approach. Case studies.

Life-cycle Analysis (LCA): Introduction – history and definition of LCA, LCA stages – definition of goal and scope, level of detail for boundaries, natural ecosystem boundaries, LCA inventories, input/output assessment, LCA impact and interpretation, identifying issues in the results, drawing conclusions and recommendations, prioritizing recommendations, comparative LCA modeling. Limitations of LCA. Case studies.

Industrial ecosystems: Environmental impact assessment, policy implications**,** Eco-industrial parks,

Development of industrial symbiosis, Socio-economic dimensions of industrial symbiosis.

Suggested books:

- Ashby, M.F. (2009). Materials and the Environment: Eco-Informed Material Choice. Elsevier Publishers: Amsterdam.
- Graedel, T.E., and Allenby, B.R. (2003). Industrial Ecology (2nd Edition). Pearson Education: Upper Saddle River, New Jersey.

EES 601: Aerosol Science (4)

[No. of Lectures 40-42]

Introduction and aerosol characterization: Definition, parameters for determining particle behavior, particle size, shape and density, aerosol concentrations, number, size, and mass distribution functions (moment distributions), Log-probability graphs, Hatch-Choate conversion equations, statistical accuracy

Uniform particle motion: Newton's/Stoke's law, settling velocity, mechanical mobility, slip correction factor, equivalent diameters, settling at high Reynolds numbers, stirred settling, Instruments based on settling velocity

Straight line acceleration and curvilinear motion: Relaxation time, stopping distance, curvilinear motion, Impaction, cascade and virtual impactors, time-of-flight instruments

Diffusion, Thermal and radiometric forces: Diffusion coefficients, Brownian displacement, diffusion/diffusion batteries, thermophoresis, thermophoretic precipitators, radiometric forces.

Coagulation, condensation, and evaporation: Monodisperse coagulation, polydisperse coagulation, kinematic coagulation, homogenous nucleation, Kelvin effect, condensational growth – growth laws, transported limited growth, aerosol phase, reaction-limited growth, heterogeneous condensation, nucleated condensation evaporation

Experimental methods for aerosol sampling and characterization: Microscopy, condensation particle counters, filtration – single fiber efficiency, deposition mechanisms, filter efficiency, pressure drop, membrane filters, Optical measurement instruments-definitions, extinction, scattering, visibility - nephelometers, transmissometers, electrical properties based instruments – electric fields, mobility, charging mechanisms, corona discharge, charge limits, electrostatic precipitators, differential mobility analyzer.

Atmospheric aerosols: Biogenic and anthropogenic aerosols, general features of ambient aerosol size distributions background aerosol, urban aerosol, chemical composition of urban aerosols

Suggested books:

- Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles (2nd edition), William C Hinds, John Wiley and Sons (1999)
- Smoke, Dust, and Haze: Fundamentals of Aerosol Dynamics (2nd edition), Sheldon K. Friedlander, Oxford University Press (2000)
- Atmospheric Chemistry and Physics: From Air Pollution to Climate Change (2nd edition), John H. Seinfeld, Sypros N. Pandis, Wiley-Interscience (2006)

EES 604: Air Quality Management (4)

[No. of Lectures 40-42]

Introduction Effects and sources of air pollutants, particulate matter management in India - legislation and regulatory trends. Source apportionment models-dispersion model and receptor models. Introduction to receptor modeling - chemical mass balance method, and multivariate methods.

Ambient air quality monitoring: Introduction, role and objectives of monitoring, air sampling, filter media, quality assurance, quality control, network design, instrument selection, system operation, advanced field analysis techniques, data collection and management.

Chemical analyses: Choice of appropriate filter-analysis methodology combinations. Choice of appropriate analytical techniques to quantify trace elements, anions, cations, carbonaceous aerosol. Overview of applying XRF, INAA, PIXE, PIGE, spectroscopic techniques, chromatography, colorimetry, thermal-optical analysis for chemical characterization of ambient particles.

Chemical mass balance for source apportionment: Introduction and method development, principles of CMB, model assumptions, mathematical framework, input and output data, using the model.

Factor analysis methods: Introduction to factor analysis. Principal components analysis, Absolute principal components analysis, UNMIX, SAFER, positive matrix factorization (PMF), advantages of PMF, mathematical framework of PMF, algorithms, penalty functions, estimation of weights, estimation of the number of factors, factor rotations, mass apportionment.

Trajectory ensemble methods: Potential source contribution function (PSCF), Residence time weighted analysis (RTW), quantitative trajectory bias analysis (QTBA), semi-quantitative trajectory bias analysis (SQTBA)

PM management in India: Applicability of receptor models. Model selection. Case studies, review of recent literature, and future directions.

SUGGESTED BOOKS

- Receptor Modeling for Air Quality Management, Philip K. Hopke, Elsevier (1991)
- Fundamentals of Atmospheric Modeling (2^{nd} edition), Mark Z. Jacobson, Cambridge University Press (2005). Label 1

CS101: Introduction to Computers

- Basic Component of a Computer System: CPU and main Memory; Disk Storage; Input and output units; function of each component.
- Hardware and Software; System Software and Applications Software; Client Server architecture; Desktops, workstations, Server & Clusters.
- Operating systems, Features of a widely used operating environment such as MS WINDOWS; UNIX or LINUX, comparison of operation environments.
- Introduction to computer networking
- Architecture of Networking
- Programming
- 3 hours of laboratory work per week

Suggested Text/Reference Books:

- B Kernighan and D M Ritchie, *The C Programming Language*, Pretice-Hall India, New Delhi.
- H M Deitel and P J Deitel, *C: How to Program*, Prentice-Hall, New Jersey.
- H M Deitel and P J Deitel, *JAVA: How to Program*, Prentice-Hall, New Jersey.
- H M Deitel and P J Deitel, *PYTHON: How to Program*, Prentice-Hall, New Jersey.
- Notes and internet printouts of material on MS WINDOWS, UNIX and LINUX.
- (N.B. The choice of the programming textbook will depend on the programming language to be taught)

ENG 101: English and Communication

Course Objectives This course imparts instruction in the use of English language for communicative purposes, and aims to develop the reading comprehension, writing, speaking and listening skills of the student. The Language Laboratory component, apart from seeking to enhance the listening skills, provides training in spoken language in various communicative situations. Instruction is carried out for effective individual attention.

Course Contents

Reading Comprehension Skills
Discovering structure; identifying themes and sub-themes; understanding and interpreting facts; distinguishing facts from opinions and specific from general statements; searching for information; drawing information and making generalizations.

Writing Skills
Developing a composition using various techniques like definition, classification, analogy, etc.; Descriptive narrative, argumentative and expository techniques in writing; Technical writing

Language Skills

(a) Common Grammatical Mistakes: Sentence fragments, Comma splice, Run-together-fused sentences; Faulty agreement and reference of pronouns; Shifts in point of view; Mixed constructions; Omissions; Incomplete and illogical comparisons

(b) Diction: Denotation and connotation; Exactness, appropriateness and effectiveness; Idiomatic usage; Colloquialisms

(c) Strategies: Economy, emphasis, Clarity, concreteness, unity and coherence

Spoken Language Skills

Descriptive, narrative, argumentative and expository techniques in spoken language use