INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH THIRUVANANTHAPURAM

An autonomous institution under the

Ministry of Human Resource Development, Government of India

CURRICULUM AND SYLLABUS FOR THE BS-MS DUAL DEGREE PROGRAMME

2019-20

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Contents

Structure and Syllabus

FIRST FOUR SEMESTERS

FOUNDATION COURSES FOR FIRST TWO YEARS (4 SEMESTERS)

Semester –I						Semester -II					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 111	Biological Diversity and Evolution	3	1	0	3	BIO 121	Biological Structure and Function	3	1	0	3
CHY 111	Atomic Structure & Chemical Bonding	3	1	0	3	CHY 121	Concepts in Inorganic Chemistry	3	1	0	3
MAT 111	Single Variable Calculus	3	1	0	3	MAT 121	Introduction to Algebra	3	1	0	3
PHY 111	Mechanics	3	1	0	3	PHY 121	Electromagnetism	3	1	0	3
IDC 111	Mathematical Tools-I	2	0	2	3	IDC 121	Mathematical Tools-II	2	0	2	3
HUM 111	Communication Skills	1	0	0	1	HUM 121	Humanities	1	0	0	1
BIO 112	Biology Lab-I	0	0	3	1	BIO 122	Biology Lab-II	0	0	3	1
CHY 112	Chemistry Lab-I	0	0	3	1	CHY 122	Chemistry Lab-II	0	0	3	1
PHY 112	Physics Lab-I	0	0	3	1	PHY 122	Physics Lab-II	0	0	3	1
Total		**15**	**4**	**11**	**19**	**Total**		**15**	**4**	**11**	**19**
Cumulative Credits at the End of First Year: 38											
Semester -III						**Semester -IV**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 211	Genetics	3	1	0	3	BIO 221	Cell Biology and Signaling	3	1	0	3
CHY 211	Basic Concepts in Organic Chemistry	3	1	0	3	CHY 221	Principles of Physical Chemistry	3	1	0	3
MAT 211	Multi Variable Calculus	3	1	0	3	MAT 221	Introduction to Probability and Statistics	3	1	0	3
PHY 211	Optics	3	1	0	3	PHY 221	Thermal &Statistical Physics	3	1	0	3
IDC 211	Physical Principles in Biology	3	1	0	3	IDC 221	Principles & Applications of Spectroscopy	3	1	0	3
HUM 211	Humanities	1	0	0	1	HUM 221	Humanities	1	0	0	1
BIO 212	Biology Lab-III	0	0	3	1	BIO 222	Biology Lab-IV	0	0	3	1
CHY 212	Chemistry Lab-III	0	0	3	1	CHY 222	Chemistry Lab-IV	0	0	3	1
PHY 212	Physics Lab-III	0	0	3	1	PHY 222	Physics Lab-IV	0	0	3	1
Total		**16**	**5**	**9**	**19**	**Total**		**16**	**5**	**9**	**19**
Cumulative Credits at the End of Second Year: 76											

BIOLOGY MAJOR

Major in Biology (Third to tenth semester)

Semester –V							Semester -VI					
Course	**Course Name**	**L**	**T**	**P**	**C**		**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 311	Microbiology	3	0	0	3		BIO 321	Structural Biology	3	0	0	3
BIO 312	Advanced Genetics and Genomics	3	0	0	3		BIO 322	Immunology	3	0	0	3
BIO 313	Physiology	3	0	0	3		BIO 323	Cell Biology	3	0	0	3
BIO 314	Biochemistry	3	0	0	3		BIO 324	Molecular Biology	3	0	0	3
BIO 315	Advanced Biology Lab-I	0	0	9	3		BIO 325	Advanced Biology Lab-II	0	0	9	3
Total		**12**	**0**	**9**	**15**		**Total**		**12**	**0**	**9**	**15**
Cumulative Credits at the End of Third Year: 106												
Semester –VII							**Semester -VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**		**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 411	Developmental Biology	3	0	0	3		BIO 4201	Elective -IV	3	0	0	3
BIO 4101	Elective -I	3	0	0	3		BIO 4202	Elective -V	3	0	0	3
BIO 4102	Elective -II	3	0	0	3		BIO 4203	Elective -VI	3	0	0	3
BIO 4103	Elective -III	3	0	0	3		BIO 4204	Elective -VII	3	0	0	3
BIO 412	Advanced Biology Lab-III	0	0	9	3							
Total		**12**	**0**	**0**	**15**		**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 133												
Semester –IX							**Semester -X**					
Course	**Course Name**	**L**	**T**	**P**	**C**		**Course**	**Course Name**	**L**	**T**	**P**	**C**
BIO 511	Major Project-Phase I	9	0	0	9		BIO 521	Major Project-Phase II	15	0	0	15
Total		**9**	**0**	**0**	**9**		**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 157												

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

CHEMISTRY MAJOR

MAJOR IN CHEMISTRY (THIRD YEAR TO FIFTH YEAR)

Semester –V						Semester -VI					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
CHY 311	Coordination Chemistry	3	0	0	3	CHY 321	Organometallics and Bioinorganic Chemistry	3	0	0	3
CHY 312	Stereochemistry-Principles & Applications	3	0	0	3	CHY 322	Methods in Structure Determination	3	0	0	3
CHY 313	Quantum Chemistry	3	0	0	3	CHY 323	Pericyclic Reactions and Reactive intermediates	3	0	0	3
CHY 314	Group Theory in Chemistry	3	0	0	3	CHY 324	Theoretical Spectroscopy	3	0	0	3
CHY 315	Chemical Kinetics	3	0	0	3	CHY 325	Inorganic Chemistry Lab	0	0	9	3
CHY 316	Organic Chemistry Lab	0	0	9	3						
Total		**15**	**0**	**9**	**18**	**Total**		**12**	**0**	**9**	**15**
Cumulative Credits at the End of Third Year: 109											
Semester –VII						**Semester -VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
CHY 411	Chemistry of Solids & Materials	3	0	0	3	CHY 421	Chemistry of s,p and f-block elements	3	0	0	3
CHY 412	Chemistry of C-C and C-X Bonds	3	0	0	3	CHY 422	Physical Organic Chemistry	3	0	0	3
CHY 413	Instrumental Methods	4	0	0	4	CHY 423	Advanced Organic Chemistry	3	0	0	3
CHY 414	Physical Chemistry Lab	0	0	9	3	CHY 424	Electrochemistry and Statistical Thermodynamics	3	0	0	3
CHY 4101	Elective-I	2	0	0	2						
CHY 4102	Elective-II	3	0	0	3						
Total		**15**	**0**	**9**	**18**	**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 139											
Semester –IX						**Semester -X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
CHY 511	Major Project - Phase I	9	0	0	9	CHY 521	Major Project - Phase II	15	0	0	15
Total		**9**	**0**	**0**	**9**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 163											

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

MATHEMATICS MAJOR

MAJOR IN MATHEMATICS (THIRD YEAR TO FIFTH YEAR)

Semester –V						Semester -VI					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
MAT 311	Real Analysis	3	0	0	3	MAT 321	Complex Analysis	3	0	0	3
MAT 312	Abstract Algebra	3	0	0	3	MAT 322	Measure Theory and Integration	3	0	0	3
MAT 313	Linear Algebra	3	0	0	3	MAT 323	Galois Theory & Commutative Algebra	3	0	0	3
MAT 314	Numerical Analysis	3	0	0	3	MAT 324	Theory of Ordinary Differential Equations	3	0	0	3
MAT 315	Number Theory and Cryptography	3	0	0	3	MAT 325	General Topology	3	0	0	3
Total		**15**	**0**	**0**	**15**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Third Year: 106											
Semester –VII						**Semester -VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
MAT 411	Functional Analysis	3	0	0	3	MAT 421	Probability Theory and Stochastic Process	3	0	0	3
MAT 412	Analysis on Manifolds	3	0	0	3	MAT 422	Differential Geometry	3	0	0	3
MAT 413	Partial Differential Equations	3	0	0	3	MAT 4201	Elective-III	3	0	0	3
MAT 4101	Elective I	3	0	0	3	MAT 4202	Elective-IV	3	0	0	3
MAT 4102	Elective II	3	0	0	3						
Total		**15**	**0**	**0**	**15**	**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 133											
Semester –IX						**Semester -X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
MAT 511 A	Major Project – Phase I	6	0	0	6	MAT 521	Major Project –Phase -II	15	0	0	15
MAT 511 B	Research Elective	3	0	0	3						
Total		**9**	**0**	**0**	**9**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 157											

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

PHYSICS MAJOR

Semester –V						**Semester –VI**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
PHY 311	Mathematical Methods	3	0	0	3	PHY 321	Statistical Mechanics	3	0	0	3
PHY 312	Classical Mechanics	3	0	0	3	PHY 322	Condensed Matter-I	3	0	0	3
PHY 313	Electronics-I	3	0	0	3	PHY 323	Electronics-II	3	0	0	3
PHY 314	Quantum Mechanics-I	3	0	0	3	PHY 324	Electrodynamics & Special Theory of Relativity	3	0	0	3
PHY 315	Advanced Physics Experiments Lab-I	0	0	9	3	PHY 325	Advanced Physics Experiments Lab-II	0	0	9	3
Total		**12**	**0**	**9**	**15**	**Total**		**12**	**0**	**9**	**15**
Cumulative Credits at the End of Third Year: 106											
Semester –VII						**Semester –VIII**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
PHY 411	Experimental Methods	3	0	0	3	PHY 421	High Energy Physics	3	0	0	3
PHY 412	Condensed Matter-II	3	0	0	3	PHY 422	Atomics & Molecular Physics	3	0	0	3
PHY 413	Quantum Mechanics-II	3	0	0	3	PHY 423	Computational Techniques & Programming Language	3	0	0	3
PHY 414	Advanced Physics Experiments Lab-III	0	0	9	3	PHY 42XX	Elective-II	3	0	0	3
PHY 41XX	Elective-I	3	0	0	3						
Total		**12**	**0**	**9**	**15**	**Total**		**12**	**0**	**0**	**12**
Cumulative Credits at the End of Fourth Year: 133											
Semester –IX						**Semester –X**					
Course	**Course Name**	**L**	**T**	**P**	**C**	**Course**	**Course Name**	**L**	**T**	**P**	**C**
PHY 511	Major Project Phase I	9	0	0	9	PHY 521	Major Project Phase II	15	0	0	15
PHY 51XX	Elective-III	3	0	0	3						
Total		**12**	**0**	**0**	**12**	**Total**		**15**	**0**	**0**	**15**
Cumulative Credits at the End of Fifth Year: 160											

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

Biology Syllabus

THEORY COURSES

BIO 111 Biological Diversity and Evolution [3103]

Overview of Biology: What is life? Characteristics of living organisms; Importance of studying biology; Scales in biology (molecules (including DNA), organelles, cells, tissues, organs, organisms, populations, communities and ecosystems); Disciplines of biology in relation to these scales; Origins of life.

Principles of Evolutionary Biology: History of evolutionary thinking - ideas that formed the basis of modern understanding of evolution; Genes and alleles; Fundamental concepts (variation, selection, units of selection, fitness, adaptation); Prerequisites for evolution by natural selection; Evidence for natural selection and evolution; Types of selection (directional, stabilizing, disruptive); Evolution without selection (genetic drift, gene flow); Species concepts and speciation; Phylogenetics (basic terminology, tree of life, phylogenetic reconstruction, molecular dating); Macroevolutionary patterns (mass extinction, adaptive radiation, convergent evolution, divergent evolution).

Principles of Ecology: Biomes; Ecosystems (trophic levels, trophic structure, energy transformation, gross and net production, primary productivity, secondary productivity); Ecosystem types (tropical, temperate, subtropical); Population ecology (population characteristics, growth, life history strategies, population regulation, metapopulations); Community ecology (ecological succession, microhabitats, niche, structure of communities); Species interactions (predation, parasitism and mutualism).

Behavioural ecology: Adaptive value of behaviour; Sexual selection; Mating systems; Kinship; Cooperation; Sociality (altruism, cooperation, kin selection, reciprocal altruism, etc.); Optimal foraging theory; Parental care; Social symbiosis.

Biodiversity and conservation biology: Taxonomy and phylogenetic systematics; Diversification of life - a phylogenetic perspective; Diversifica-

tion of life - a timeline; Measuring extant diversity; Threats to extant biodiversity (habitat loss and degradation, Invasive species, Pollution, Overexploitation, Global climate change); In-situ and ex-situ conservation; Biodiversity of India; Island biogeography.

REFERENCES:

1. Molles, *Ecology: Concepts and Applications*
2. Futuyma, *Evolution*
3. Barton *et al.*, *Evolution*
4. Stearns and Hoekstra, *Evolution: An Introduction*
5. Nicholas Gotelli, *A primer of Ecology*
6. Begon *et al.*, *Ecology: From Individuals to Ecosystems*

BIO 121 Biological Structure and Function [3103]

Biological molecules and their structure and functions.

Stabilizing interactions in biological molecules.

Principles of biophysical chemistry (pH, reaction kinetics, thermodynamics).

An introduction to metabolic pathways.

Biological catalysis, enzymes and kinetics, enzyme regulation.

Basic physiological processes in plants and animals: Nervous system and sensory systems, muscles and movement, respiration and exchange of gases, heart and circulatory system, kidney and osmo-regulation, plant responses to light, flower development.

REFERENCES:

1. Rodney F Boyer, *Concepts in Biochemistry*, John Wiley & Sons; 3rd Edition edition (2 December 2005).
2. Thomas Miilar, *Biochemistry Explained: A Practical Guide to Learning Biochemistry*, CRC Press; 1 edition (30 May 2002).
3. Lubert Stryer *et al.*, *Biochemistry*, 6th Edition edition (14 July 2006).
4. David L Nelson, and Michael M Cox *et al.*, *Lehninger principles of biochemistry*, WH Freeman; 7th ed. 2017 edition (1 January 2017).
5. Richard Hill, Gordon Wyse, and Margaret Anderson, *Animal Physiology*, OUP USA; 4 edition (5 October 2017).
6. G Ray Noggle and, George J Fritz , *Introductory Plant Physiology*, Prentice Hall India Learning Private Limited; 2 edition (1986).

BIO 211 Genetics [3103]

Introduction to genetics.

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

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

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

Model organisms and studies on molecular and genetic interactions.

Basics of Expression genetics, transcription, translation.

Genome composition and organization, Cot analysis.

Chromosome structure and function.

Mitosis and Meiosis.

DNA replication, Mutations.

REFERENCES:

1. Anthony J F Griffiths *et al.*, *An Introduction to Genetic Analysis*
2. Watson *et al.*, *Molecular Biology of the Gene*
3. Jocelyn E Krebs *et al.*, *Lewin's Genes*
4. Richard Kowles, *Solving Problems in Genetics*

BIO 221 Cell Biology and Signalling [3103]

Structure of prokaryotic and eukaryotic cells.

Membrane structure and function.

Structural organization and function of intracellular organelles.

Cell division and cell cycle.

Principles of signal transduction and role of secondary messengers (basic level).

Hormones and their receptors.

Cellular communications.

Signalling in cancer.

Signalling in immune systems.

REFERENCES:

1. Gerald Karp, *Cell Biology*, WILEY (Feb. 4th, 2013).
2. Wayne M. Becker *et al.*, *World of the Cell*, Benjamin Cummings; 7th edition (February 19, 2008).
3. Bruce Alberts *et al.*, *Essential Cell Biology* Richard Goldsby and Thomas J, &F/Garland, 4th Edition, (2014).
4. Alberts, Bruce *Molecular Biology of the Cell*, Garland Science; 5th edition (2 January 2008).
5. Kindt, Kuby, *Immunology*, W. H. Freeman; 6th edition (9 October 2006).

BIO 311 MICROBIOLOGY [3003]

History of Microbiology, microbial diversity, microbial nutrition and growth kinetics.

Viruses and prions: Introduction, general characteristics, viruses of bacteria and archea.

Microbial physiology: structure of microbes, autotrophic and heterotrophic metabolisms, growth and its control factors.

Microbial development: division, sporulation, organelle (flagella, pili, holdfast, chemosensory apparatus etc.) development.

Overview of microbial development with examples from model systems such as Bacillus, cyanobacteria, yeast, filamentous fungi and protozoa.

Microbial communication and chemosensory response.

Microbial pathogenesis: types, mode of infection with examples of human and plant pathogens. Antimicrobial agents and their mode of action.

Applied microbiology: biodegradation, bioremediation, fermentation, use of bacteria in recombinant protein production.

REFERENCES:

1. Willey, Joanne M; Sherwood, Linda; Woolverton, Christopher J; *Prescott Harley Klein's Microbiology*, McGraw-Hill, 7th Edition, 2008.
2. Cardona (2016) *The Progress of Therapeutic Vaccination with Regard to Tuberculosis*, Frontiers in Microbiology 7
3. Wai-Leung Ng and Bonnie L. Bassler (2009) *Bacterial Quorum-Sensing Network Architectures Annu Rev Genet*, 2009; 43: 197?222. doi:10.1146/annurev-genet-102108-134304.
4. chemotaxis: http://chemotaxis.biology.utah.edu/ParkinsonLab/projects/ecolichemotaxis/ecolichemotaxis.html
5. Endotoxin: http://textbookofbacteriology.net/endotoxin.html

BIO 312 ADVANCED GENETICS AND GENOMICS [3003]

Model genomes.

Scale of genome variation: mutations, SNPs, indels, structural variation, ploidy changes.

Methods to study genomes: PCR, microarrays, next generation sequencing technologies, comparative genomic hybridization, pulse ?eld gel analysis, synthetic genetic array analysis.

DNA Repair and Recombination.

Genome mapping: genetic markers, genetic and physical maps, recombination rates, linkage analysis, linkage disequilibrium, haplotype analysis, meiotic hotspots.

Co-relating genotype with phenotype: forward and reverse genetics, candidate gene approach, insertional mutagenesis, screening genomic libraries, complex trait analysis.

Genomics and medicine: genome sequencing, personalized medicine.

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

REFERENCES:

1. TA Brown, *Genomes*, 4, Garland Science, 4th edition, Published May 24, 2017.
2. Tom Strachan, Andrew Read, *Human Molecular Genetics*, Garland Science, 5th edition, 20-Dec-2018.
3. Greg Gibson and Spencer V. Muse, *A Primer of Genome Science*, Sinauer Associates, Third Edition, February 15, 2010

BIO 313 PHYSIOLOGY [3003]

Animal physiology: Mechanisms and origin of animal physiology.

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

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

Biological Clocks: internal biological clocks; circadian rhythms.

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

metabolism.

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

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

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

Circulatory system: circulatory systems in invertebrates and vertebrates.

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

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

Animal navigation and migration: why and how do animals migrate?

Physiological changes during migration, Physiological diseases.

REFERENCES:

1. *Animal Physiology*, Richard W Hill, Gordon A Wyse and Margaret Anderson: Sinauer Associates. 4th Edition.
2. *Eckert?s Animal Physiology: Mechanisms and Adaptations*, David Randall, Warren Burggen and Kathleen French: 5th edition

BIO 314 BIOCHEMISTRY [3003]

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

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

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

Nucleic acid metabolism: purine and pyrimidine biosynthesis.

Bioenergetics: Oxidation reduction reactions.

Molecular chaperones in protein folding, experimental strategies to study

protein mis-folding and disease, regulation of metabolism through metabolic networks, metabolic messengers, generation of NO and oxygen radicals and their roles.

Secondary metabolism.

Analytical Methods in Biochemistry.

REFERENCES:

1. Rodney F Boyer, *Concepts in Biochemistry*, John Wiley & Sons; 3rd Edition edition (2 December 2005).
2. Thomas Millar, *Biochemistry Explained: A Practical Guide to Learning Biochemistry*, CRC Press; 1 edition (30 May 2002).
3. Lubert Stryer et al., *Biochemistry*, W. H. Freeman; 6th Edition edition (14 July 2006).
4. John E. McMurry and Tadgh Begley, *The Organic Chemistry of Biological Pathways*, WH Freeman; 2 edition (11 December 2015).
5. Laurence A Moran, *Principles of Biochemistry Pearson New International Edition*, Pearson; 5 edition (30 July 2013).
6. David L. Nelson and Michael M. Cox, Lehninger , *Principles of Biochemistry*, WH Freeman; 7th ed. 2017 edition (1 January 2017).

BIO 321 STRUCTURAL BIOLOGY [3003]

Principles of proteins and nucleic acid structures, conformation and analysis. Structural Bioinformatics. Molecular phylogenetic analysis. Tools for analysing protein structures to understand the molecular basis of their functions. Structure Based Drug Design. X-ray crystallography, electron microscopy and NMR in structural biology. Graphics and structural validation. Structural databases. Other biophysical and spectroscopic techniques to understand conformations of biomolecules.

REFERENCES:

1. Schulz GE and Schirmer RH, *Principles of protein structure*, Springer-Verlag, 1979.
2. Branden C and Tooze J, *Introduction to protein structure*, Garland Science, 2nd Edition. 1999.
3. Stout GH and Jensen LH, *X-ray structure determination, John;Wiley and Sons Inc.*, New York, 1989.
4. Jan Drenth, *Principles of protein crystallography*, Springer Science & Business Media, 2007.

5. Liljas A, Liljas L, Piskur J, st Lindblom G, Nissen P and Kjeldgaard M. (2009). *Textbook of Structural Biology*, 1st edition, World Scientific Publishing, 2009.
6. Joachim Frank, *Three-Dimensional Electron Microscopy of Macromolecular Assemblies*, Academic Press, 1996.
7. A. K. Downing, *Protein NMR techniques, Methods in Molecular Biology*, Volume 278, 2004.

BIO 322 IMMUNOLOGY [3003]

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

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

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

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

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

The MHC and Ag presentation and T cell development.

Immunity mechanisms in disease (allergies, autoimmunity, immuno-deficiency).

Immunotherapy (clinical use of monoclonal antibodies).

Tumour Immunology.

REFERENCES:

1. Coico, Richard, *Immunology: A Short Course, Wiley-Blackwell*, 6th Revised edition (20 February 2009).
2. Paul, William E, *Fundamental Immunology*, LWW; Seventh edition (December 19, 2012).
3. Owen, Judith A.; Kuby *Immunology*, W. H. Freeman; 7th edition (January 25, 2013).
4. Alberts, Bruce, *Molecular Biology of the Cell: Garland Science*, 5 editions (2 January 2008).

BIO 323 CELL BIOLOGY [3003]

Methods used in cell biology: microscopy, cell sorting, fractionation of cellular components, radioisotopes and antibodies as tools to study cellular functions.

Cell membrane: organization and composition of the cell membrane, structural micro-geneity and micro-domain in membrane, membrane transport-endocytosis and exocytosis Vesicular transport system and intracellular trafficking, protein targeting.

Organelle biogenesis.

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

Cell-cell signaling: overview of extracellular signaling, cell surface receptors, cell signaling during growth and differentiation.

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

Cell death: Apoptosis and autophagy pathways.

REFERENCES:

1. Gerald Karp, *Cell Biology*, WILEY (Feb. 4th, 2013).
2. Andrew Murray & Tim Hunt, *Cell Cycle*, Oxford University Press, USA, 1Edition 1993
3. Lodish, Berk et al.,*Molecular Cell Biology*, Wh Freeman & Co, 6TH Edition 2007.

BIO 324 MOLECULAR BIOLOGY [3003]

Molecular aspects of RNA processing, transcription and translation.

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

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

Non-coding RNA: Biogenesis and its function.

Recombinant DNA technology and molecular cloning.

REFERENCES:

1. Bruce Alberts, Alexander D. Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts and Peter Walter, *Molecular Biology of the Cell*, 6TH Edition, 2015.
2. Errol C Friedberg, Graham C Walker, Wolfram Siede, Richard D Wood, Roger A Schultz, and, Tom Ellenberger, *DNA Repair and Mutagenesis*, ASM Press 2nd Edition, 2006.

3. Mehta, A. and Haber J. E. (2014) *sources of DNA double strand breaks and Models of Recombination DNA repair Cold Spring* Harb Perspect Biol 6: a016428.
4. Anand, R.P, Lovett, S.T. and Haber J.E. (2013) *Break Induced DNA Replication*. Cold Spring Harb Perspect Biol 5: a010397.
5. Matthew Meselson and Franklin W. Stahl (1958) *The replication of DNA in Escherichia coli*. PNAS, 44 (7) 671-682.

BIO 411 DEVELOPMENTAL BIOLOGY [3003]

Course Content:
Basic Concepts and history of developmental biology - Model systems: developmental model organisms: Sea urchin, Drosophila, Xenopus, Chick Early embryonic development: Cleavage, gastrulation and development of germinal layers; Maternal inheritance; Maternal to zygotic transition of gene expression; Early control of cell cycle Morphogenesis and development of body plan, Cellular differentiation and Organogenesis: neurogenesis and limb development; Cytoskeleton, cell adhesion and cell migration in organogenesis Growth and post-embryonic development: Hormonal control of metamorphosis in Drosophila and amphibians, Germ cells and sex determination, Regeneration and tissue repair Evolution and development, Defects in development and diseases: Neural tube defects, limb formation defects, growth defects.

REFERENCES:

1. Scott F Gilbert, *Principles of Development*, Sinauer, 10th Ed, 2014.
2. Lewis Wolpert and Cheryll Tickle, *Principles of Development*, OUP, 4th Ed, 2011.

IDC 211 Physical Principles in Biology [3003]

Physical biochemistry of the cell: Chemical forces translation and rotation, diffusion, directed movements, bio-molecules as machines, work, power and energy, thermal, chemical and mechanical switching of biomolecules, Responses to light and environmental cues.

Physical principles of molecular structure: organization of biomolecules, molecular census in size and time, macromolecular assemblies, sizing up HIV, channels, transporters and motors.

Molecular recognition: principles of specificity in biological recognition,

hormone-receptor interaction, antigen-antibody interaction, transient interactions, importance of transient interaction in biology.

Linearity and non-linearity in biological systems: Definitions and example of linear and non-linear systems. Representing linear and nonlinear functions and applications.

Stochasticity in Biological systems.

REFERENCES:

1. John Kuriyan, *The Molecules of Life: Physical and Chemical Principles*, Garland Science (Taylor & Francis group); 1 edition, 2013.
2. Rob Phillips et al., *Physical Biology of the Cell*, Garland Science. 2nd Edition. 2012.
3. Peter Atkins and Julio de Paula. *Physical Chemistry for the Life Sciences*, Oxford University Press. 2nd Edition. 2011.

List of electives

1. Biological Data Analysis
2. Neurobiology
3. Plant Molecular Biology
4. Evolutionary Ecology
5. Stem Cells and Regenerative Medicine
6. Chronobiology
7. Advanced Developmental Biology
8. Bacterial Genetics
9. Animal Behaviour
10. Research Methodology
11. Scientific Writing (1 Credit)
12. Biosafety and Regulation (1 Credit)
13. Bioinformatics
14. Host-Pathogen Interactions
15. Biodiversity and Field Biology
16. Synthetic Biology
17. Cancer Biology
18. Genome Stability
19. Ecological Ineractions

Syllabi of selected electives

Cancer Biology[3003]
Prerequisite: Cell Biology (BIO323) and Molecular Biology (BIO324)

The objective of this course is to introduce students to topics on fundamental cancer biology from basic research to therapy. This course aims to provide an overview of the biology and pathology of cancer. The course will educate students on various genetic and molecular changes normal cells undergo during transformation into malignant cancer cells. These modifications include unregulated cell proliferation, evasion of cell death and metastasis. The course describes factors that contribute to cancer development and discuss cancer prevention and treatment options.
Types of cancers (both solid tumors and leukemias) and hall marks of cancers.

The common cellular and molecular mechanisms that are deregulated in cancerous cells, and how does their deregulation contribute to the development of cancer?

Oncogenes and their role in tumor development.

Tumor suppressor genes and their role in neoplasia.

Gene translocations and types of gene mutations that contribute to tumour formation.

Chronic inflammation and infectious agents and their role in cancer development.

Cancer detection/screening and therapy.

REFERENCES:

1. Weinberg, Robert A. The Biology of Cancer, Second Edition. New York: Garland Science, 2013.

Reviews on specific topics related to cancer.

Biological data analysis [3003]
Concept of data, structure, security, storage, retrieval.

Biological data and their sources.

Methods for data exploration.

Concept of data mining.

Analysis of nucleic acid sequences- composition and asymmetry, repeats (direct, inverted and interspersed), similarity searches, both global and local algorithms, details of blast algorithms.

Analysis of protein sequences, similarity searches including remote homologue searches.

Motif finding algorithms.

RNA structure analysis.

Next generation sequencing and principles of NGS data analysis.

Using R for analysis of biological data.

REFERENCES:

1. Jonathan Pevsner, *Bioinformatics and Functional Genomics*, Chichester, West Sussex, UK; John Wiley and Sons, Inc, 3rd Edition, 2015.
2. David Mount, *Bioinformatics: Sequence and Genome Analysis*, New Delhi: CBS Publishers & Distributors, 2nd, 2005.
3. Robbe Wunschiers, *Computational Biology: A Practical Introduction to Biodata Processing and Analysis with Linux, MySQL, and R*, Heidelberg: Springer, c2013. Heidelberg: Springer, 2nd, 2013.
4. Peter Dalgaard, *Introductory Statistics with R*, New York: Springer, 2nd, 2008.
5. Michael C. Whitlock and Dolph Schluter, *The Analysis of Biological Data*, Greenwood Village, Colorado: Roberts And Company Publishers, 2nd, 2015.

Neurobiology [3003]

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

REFERENCES:

1. John G. Nicholls, A. Robert Martin, David A. Brown, Mathew E. Diamond, David A. Weisblat, and Paul A. Fuchs, *From neuron to brain*, Sinauer Associates, Inc. Fifth edition, November 2011.
2. Mark F. Bear, Barry W. Connors, Michael A. Paradiso, *Neuroscience: Exploring the Brain*, Lippincott Williams & Wilkins, Third Edition, April 1995.

Plant molecular biology[3003]
A general introduction to embryonic and postembryonic plant development, regulatory action of plant hormones in controlling the continuous patterning, Enhancer and suppressor screens to design regulatory network, tissue specific mis-expression and Ectopic over expression studies and their implications, genetic screens to identify upstream regulators, molecular analysis to identify downstream regulators of patterning regulators (transcription factors), molecular genetic interactions to generate regulatory network of shoot and root meristem function.

Stem cell and regeneration (nursery rhymes across the kingdom): regulatory network controlling the stem cell initiation and maintenance in plants, molecular mechanisms of regeneration and reprogramming of cell fate, pluripotency, multipotency and totipotency in plants.

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

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

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

REFERENCES:

1. Ottoline Leyser, Stephen Dey. *Mechanisms in Plant Development*, Blackwell Science Ltd. index. ISBN: 0-86542-742-9. 2003.

Evolutionary Ecology [3003]
Recapitulation of fundamental concepts of evolution: Selection; Fitness; Adaptation; Types of selection; Evolution without selection.

Prey-predator interactions: Predation as one of the strongest selective forces; Aposematism; Frequency Dependent Predation and Selection; Batesian and Mllerian mimicry; Crypsis (background matching, disruptive colouration, countershading, deflection, motion dazzle etc); Deimatic displays; Anti-herbivory strategies in plants (constitutive and induced defenses, secondary metabolites).

Phylogenetics: Recapitulation of basic phylogenetic terminology (rooted

and unrooted trees, monophyly and non-monophyly, sister grouping, etc). Phylogenetic reconstruction (datasets, advantages of molecular data, optimality criteria - maximum parsimony and model based methods, measures of clade support); Gene trees versus species trees; Phylogenomics; Molecular dating.

Historical biogeography: Biogeographic realms; Understanding geographic patterns of speciation using phylogenies; Vicariance, dispersal and sympatric speciation; Plate tectonics and its impact on diversification; Importance of dispersal for diversification; Geodispersal.

Phylogenetic Comparative Methods: Testing evolutionary hypotheses using phylogenetic information, Importance of taking into account phylogenetic non-independence, Order of origin of traits, Correlations across traits, Diversification rates.

Phylogeography and Population genetics: Understanding history of populations using Haplotype Networks; HW Equilibrium; Population genetic structuring, Conservation genetics.

Coevolution: Coevolution of various types of interactions; Diffuse coevolution; Arms race.

Phenotypic plasticity: Reaction norms; Polyphenisms; Adaptive plasticity; Reversible versus irreversible plasticity; Inducing environment versus adaptive environment; Genetic assimilation.

Sensory ecology: Sensory systems (vision, olfaction and special senses); Signalling and communication in plants and animals; Plant-animal interactions; Mechanisms of learning, memory and cognition.

Cooperation and conflict in animal societies: Kinship and conflict with kin (parent-offspring conflict, sibling rivalry, kin recognition); Habitat selection and territoriality; Aggression; Alarm signals; Social learning.

Macroevolutionary patterns: Studying macroevolutionary patterns using phylogenies; Some well-studied macroevolutionary patterns (adaptive radiations, convergent and parallel evolution; Latitudinal diversity gradient, ecological rules, e.g., Bergmann's and Allen's rules).

Hominid evolution and ecology

REFERENCES:

1. Graeme D. Ruxton, William L. Allen, Thomas N. Sherratt, and Michael P. Speed. *Avoiding Attack - The Evolutionary Ecology of Crypsis, Aposema-*

tism, and Mimicry, Oxford University Press, Second Edition, 26 September 2018.
2. Mary Jane West-Eberhard, *Developmental plasticity and evolution*, Oxford University Press, first edition, 13 March 2003.
3. Douglas J. Futuyma and Mark Kirkpatrick, *Evolution*, Oxford University Press Fourth Edition, 08 Jun 2017.
4. von der Emde, Gerhard, Warrant, Eric (Eds.) *The Ecology of animal senses*, Springer, 2016.
5. Carlos M. Herrera, Olle Pellmyr. *Plant-Animal Interactions: An Evolutionary Approach*,1st Edition. 2012.
6. Lee Alan Dugatkin. *Principles of Animal Behavior*, Second Edition. W. W. Norton & Company. 2008

Stem cells and regenerative medicine [3003]
(Prerequisite: Developmental Biology)

Introduction to Stem cells: Basics of stem cells and principles of stemness, Early mammalian development, Evolution of stem cells.

Biology of stem cells: Cell cycle regulation in stem cells, Mechanisms of differentiation, Signal transduction (More elaborative for mechanisms involved in development), Metabolism of stem cells.

Pluripotent stem cells: Types of pluripotent stem cells; Isolation, characterization of embryonic stem cells; Generation of iPS cells and disease modeling; Biology of ES and iPS cells; Genome editing technologies; Alternative medicine.

Adult stem cells: Properties, identification and separation of various stem cells, Biological principles of HSCs; development, regulation od proliferation and differentiation, Sources of HSCs and their clinical use.

Cancer stem cells: Concepts, identification, biology, Potential application.

Stem Cell niches: Extrinsic factors in the regulation of stem cell function. Biological, physio-mechanical properties of stem cell micro-environment (for HSCs, epidermal, germ and intestinal stem cells).

Transplantation biology: Immunology of transplantation and graft rejection, Homing mechanism of transplanted stem cells.

Tissue engineering: Ex vivo expansion of stem cells, Ex vivo construction of tissues, scaffolds, bioreactors.

Stem cells in clinic: Avenues for stem cell use (metabolic, genetic diseases, cancers and trauma), Potential application of stem cells in clinic and present clinical use. Hurdles and future directions.

Methods in stem cells: In vitro methods to assay stem cells, In vivo methods to assay stem cells.

REFERENCES:

1. Essentials of Stem Cell Biology by Robert Lanza Anthony Atala (Eds.): Academic Press. 3rd Edition 2013.
2. Stem Cells: An Insider's Guide by Dr. Paul Knoepfler: World Scietific publishing Co. Pvt. Ltd. 1st Edition 2013.
3. The science of stem cells by JMW Slack: Wiley Blackwell publishers. 1st Edition 2017.
4. Stem Cells, Tissue Engineering and Regenerative Medicine by David Warburton (Ed.) World Scietific publishing Co. Pvt. Ltd. 1st Edition 2014.
5. Stem Cells Handbook by Stewart Sell (Ed.). Springer 1st edition 2013.
6. Stem Cells: A Short Course Rob Burgess. Wiley Blackwell publishers. 1st Edition 2016.
7. Principles of Tissue Engineering Robert Lanza Robert Langer Joseph Vacanti (Eds.). Academic Press 4th edition 2013.
8. The Biomedical Engineering Handbook by Joseph D. Bronzino, Donald R. Peterson. CRC Press Taylor & Francis. 1st edition. 2015.

Chronobiology [3003]

Fundamental properties of circadian clock: Entrainment, masking and zeitgebers, parametric and non-parametric entrainment, phase shift, phase response curves (PRC), temperature compensation of circadian clock.

Molecular biology of the circadian clock: The central oscillator, , molecular components of circadian pacemakers, genetics of circadian rhythms, the circadian feedback loops, post-transcriptional regulation of circadian rhythms, circadian clocks in various model organisms.

Circadian clock neuronal network: circadian pacemaker neuronal circuit, morning and evening oscillators, neurotransmitters-the chemical signals of the circuit, electrophysiological properties of the clock neurons.

Circadian photoreception: Input signals into the circadian clock, molecular pathway of circadian photoreception, light entrainment of circadian clock, extra-ocular photoreception.

Neural circuitry of sleep: Genetics of sleep, organization of sleep arousal circuit, wake promoting and sleep promoting neurotransmitters. Sleep for memory consolidation, Sleep disorders.

Circadian clock and metabolism: Central and peripheral circadian clocks,

circadian disruptions and metabolic disorders, neuro-degenerative diseases, ageing and circadian clock.

Evolution of the circadian timing system: Evolution of circadian clocks, fitness, adaptive significance of circadian clocks.

REFERENCES:

1. Jay C. Dunlap, Jennifer J. Loros, Patricia J. DeCoursey, *Chronobiology: Biological time keeping*, Sinauer Associates, Inc. Publishers, First Edition, December 2009.
2. D.S. Saunders, *Insect clocks*, Elsevier science & Technology, Third Edition, November 2002.

Advanced Developmental Biology [3003]
(prerequisite: Developmental Biology)

Syllabus: Maternal inheritance and maternal to zygotic transition during early development: molecular players in maternal inheritance; mechanisms that regulate transition from maternal to zygotic gene expression: recent genetic studies in Drosophila and Zebrafish will be discussed.
Cell migration and cell adhesion in development: cell migration and cell adhesion in early embryos; recent literature on Drosophila germ cell and border cell migration, tracheal development and dorsal closure will be discussed.
Interpretation of morphogen gradients: various models of morphogen gradient formation; functions of morphogen gradients during morphogenesis and patterning of tissues; experimental approaches to measure the morphogen gradients.
Asymmetry in the germ cells and in developing embryo: asymmetric distribution of messenger RNA and protein in germ cells and in developing Drosophila embryos, scientific papers that deal with the molecular machinery that leads to this asymmetry during early development will be referred to.
Cell Polarity in development and changes in cell polarity: epithelial cell polarity in development; players in epithelial polarity; cytoskeletal mechanisms; protein trafficking machinery in cell polarity, factors that lead to epithelial polarity loss and transition to mesenchymal states in various developmental contexts.

Development of behavior: courtship behaviour, aggression, modification of behaviour by pathogens will be dealt with.

REFERENCES:

1. Scott F Gilbert, *Principles of Development*, Sinauer, 10th Ed, 2014.
2. Lewis Wolpert and Cheryll Tickle, *Principles of Development*, OUP, 4th Ed, 2011.

Bacterial Genetics [3003]
(prerequisite: Microbiology)

Bacterial chromosome structure and replication, Mutations and repair in bacteria (classes of mutations, measuring mutations, mutator strains, mechanisms of bacterial DNA repair, SOS response), transposition, mapping of mutations, plasmids, bacterial two-hybrid systems, genetics of bacteriophages, conjugation, transformation, transduction as a tool in bacterial genetics, recombination, gene expression and transcriptional regulation in bacteria, post-transcriptional regulation in bacteria, Function and use of Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR).

REFERENCES:

1. Fundamental Bacterial Genetics, Nancy Trun and Janine Trempy, Blackwell Publishing, 2004.

Animal Behaviour [3003]
(prerequisite: Evolutionary Ecology)

Life-history strategies. Game theory. Reproductive strategies, sexual systems.

Social organization hierarchy and dominance.

Deceit, conceit, prestige. Animal personality.

Territoriality, Space and information usage.

Learning, memory and cognition.

REFERENCES:

1. Alcock, J. *Animal behavior: An evolutionary approach*, Sinauer Associates. 2013.

Genome Stability[3003]
(prerequisite: Adv. Genetics and Genomics)

DNA damage and recognition (sources and types of DNA damage, random and programmed double strand breaks, chromosome structural variations).

Cellular responses to DNA damage (signalling of DNA damage, choice of DNA repair and recombination pathways).

DNA repair mechanisms (mismatch repair, Base excision repair, Nucleotide excision repair, non-homologous end joining, Homologous recombination).

Mechanisms of meiotic recombination and chromosome segregation (Chromosome pairing and synaptonemal complex assembly, Regulation of meiotic recombination pathways, processing of Holliday junctions, spindle assembly).

Genomic instability and human disease (cancer, birth defects, genomic disorders due to chromosome structural variation), Genome editing (targeted modification of the genome using nucleases).

REFERENCES:

1. Genome Stability: James Haber, Garland Science
2. DNA Damage and Repair: Jac A. Nickoloff, Merl F. Hoekstra, Humana Press
3. DNA repair and mutagenesis: Errol C. Friedberg, American Society for Microbiology Press

Ecological Interactions[3003]
The central role of interactions in the ecology and evolution of organisms.

Interactions at different scales: Studying the process of interactions and macroevolutionary patterns generated by them; Importance of accounting for phylogenetic non-independence; Phylogenetic comparative methods to study the role of interactions in diversification.

Specialization and generalization as alternate strategies: Defining and measuring specialization and generalization; Multiple axes of specialization; When is each strategy favoured?

Insect- host plant interactions: Why are herbivorous insects so diverse - diffuse coevolution between insects and their host plants; Oviposition preference hierarchy; Larval performance hierarchy and concordance be-

tween them.

Plant- pollinator interactions: Insect pollination as a key innovation; Specialisation and generalisation in plant-pollinator interactions; Obligate mutualisms.

Experimental coevolution: What is experimental coevolution and how does this differ from other types of empirical coevolution studies; Advantages of experimental coevolution; Popularity of microbial systems in such studies; Case studies from microbial and insect systems.

Host parasite interactions: Diversity of host parasite interactions in nature; Case studies of the widespread endosymbiont Wolbachia and its insect hosts.

Inter- and intra-specific competition: Spatial and temporal mechanisms of competition avoidance; Concept of niche and niche partitioning.

Dispersal ecology: Causes and consequences of dispersal in plants and animals; invasive species and their effects on community organisation.

REFERENCES:

1. Modern Phylogenetic Comparative Methods and Their Application in Evolutionary Biology: Concepts and Practice. Edited by Lszl Zsolt Garamszegi.
2. The Geographic Mosaic of Coevolution. By John N. Thompson
3. Parasitism: The Ecology and Evolution of Intimate Interactions. By Claude Combes
4. Plant-Pollinator Interactions: From Specialization to Generalization. Edited By Nickolas M. Waser and Jeff Ollerton
5. Experimental Evolution: Concepts, Methods, and Applications of Selection Experiments. Edited By Theodore Garland and Michael R. Rose
6. Dispersal Ecology and Evolution. By Jean Clobert, Michael Baguette, Tim G Benton, James M. Bullock

Host-Pathogen Interactions

prerequisite: Immunology

Introduction to Host-pathogen interaction: Viral, Bacterial and parasite pathogens .

Pathogen external interactions, Viral pathogen attachment and entry into the host cell.

Virus replication cycle Animal models?

Experimental approaches to study Microbial pathogenesis: Identification

of virulence factors Genome-wide approaches to study host-pathogen interactions.

Monitoring host response and immunity to pathogens Pathobiology of Infection: Survival strategies of viral, bacterial and parasite pathogens. Immune response to infectious diseases Mechanisms of pathogenesis, pathogens immune evasion mechanism.

Manipulation and reprogramming of the intracellular environment.

Infection of the human host: Gastrointestinal Infections, Respiratory infections, CNS infections, and organ infections.

REFERENCES:

1. Edward K. Wagner , Martinez J. Hewlett. *Basic Virology*, 2nd Ed. Blackwell Publishing, 2005.
2. Cossart, Pascale. Boquet, Patrice, Normark, Staffan, Rappuoli, Rino, *Cellular Microbiology*, Pascale Cossart et al.. 2nd Ed, Washington, DC : ASM Press, c2005.
3. Gerald Karp, *Cell Biology,* WILEY (Feb. 4th, 2013)
4. Wayne M. Becker et al., *World of the Cell*, Benjamin Cummings; 7th edition (February 19, 2008)
5. Bruce Alberts et al., *Essential Cell Biology*, Richard Goldsby and Thomas J, & F/Garland, 4th Edition, (2014)
6. Kindt, Kuby, I*mmunology*, W. H. Freeman; 6th edition (9 October 2006)

LABORATORY COURSES

BIO 112 BIOLOGY LAB-I

Semester-long group projects designed to expose students to: A. The concept of hypothesis testing
B. Designing simple experiments to test the hypothesis
C. Data analysis and interpretation of results
D. Oral presentation of the study
E. Report writing

BIO 122 BIOLOGY LAB-II

A. Plant and animal cells under a microscope
B. Structure and function of plant tissues
C. Buffer preparation, PI value analysis of proteins
D. Quantitative analysis of biomolecules

E. Analysis of light reaction of photosynthesis by DCPIP method
F. Estimation of water potential in plant tissues
G. Protein profile by SDS-PAGE

BIO 212 BIOLOGY LAB-III
A. Mutation frequencies, fluctuation tests
B. Analyze data from crosses: theoretical problem solving
C. Mitosis
D. Meiosis
E. DNA isolation and quantification
F. Agarose gel electrophoresis

BIO 222 BIOLOGY LAB-IV
A. Cell fractionation (nuclear, mitochondrial, cytosolic)
B. Enzyme assays for mitochondrial proteins
C. Tubulin blockers or mitotic inhibitors to assess effects on proliferation
D. Image analysis

BIO 315 ADVANCED LAB COURSE I [0093]
Microbiology: Microbial growth kinetics, bacterial motility assay; antibiotics susceptibility testing, MIC

Genetics: Conjugation; Transduction; transcription; transposon mutagenesis, construction of bacterial gene deletions by homologous recombination(including primer designing; PCR; cloning; plasmid isolation; Transformation and screening for knock-outs); tetrad analysis in yeast, analysis of genomics data

Biochemistry: Identification of proteins by Western blotting, purification of proteins by chromatography techniques, analysis of protein-protein interaction by biochemical techniques, Determination of binding parameters of protein-ligand interaction.

BIO 325 ADVANCED LAB COURSE II [0093]
Structural Biology: Basic UNIX commands, shell scripts and the first C-programming; PDB and graphics visualization using Pymol/Chimera; Sequence analysis at Expasy and PDB; Protein Crystallization; Visualizing reciprocal lattice and diffraction using X-Ray View; X-ray diffraction and

data collection; Molecular Replacement; Refinement; model building and refinement; Validation of the protein structures. Analyzing protein structures Procheck, HBPLUS, DSSP, CCP4.

- Immunology: Purification and analysis of Immunoglobulins,
  - Immunoprecipitation,
  - Enzyme-linked immunosorbent assay (ELISA)
- Fluorescence-activated cell sorting (FACS) and analysis of cells, Immunostaining and imaging
- Mammalian Cell Counting
- Phagocytosis

Cell Biology: Separation of cellular organelles by density gradient; immunofluorescence imaging of cellular organelles, Analyses of cell cycle, actin and microtubule polymerization

BIO 412 ADVANCED LAB COURSE III [0093]
Biological Data Analysis: Statistical distributions of ecological parameters, Crypsis as an anti-predatory strategy, Sampling techniques for plants and insects, Spectral measurements of natural objects, Variant analysis in genomic data.

Drosophila Developmental Biology and Physiology:

1. Life cycle and external morphology of Drosophila:
   - Embryo, larval, pupal and adult stages
   - Segregation of male and female flies
   - Basics of setting up a cross
2. Dominant Vs recessive mutations:
   - External phenotypes (eye, wing and bristle)
3. Simple genetic crosses:
4. Gal4-UAS system:
   - express reaper in the eye (inducing apoptosis in the compound eyes)
   - express GFP in larval salivary glands (tissue specific expression and observation of a fluorescent protein)
   - express reaper in insulin producing neurons: (growth phenotype by blocking insulin growth factor levels)

5. Behavior studies using flies:
    - Motor neuron defects (hyperactivation or inactivation of motor neurons)
    - Feeding assays
6. Developmental biology experiments:
    - Oogenesis, border cell migration
    - Early embryonic patterning

Chemistry Syllabus

List of Courses:

Theory courses

1. CHY 311 Coordination Chemistry
2. CHY 312 Stereochemistry- Principles & Applications
3. CHY 313 Quantum Chemistry
4. CHY 314 Group Theory in Chemistry
5. CHY 315 Chemical Kinetics
6. CHY 321 Organometallics and Bioinorganic Chemistry
7. CHY 322 Methods in Structure Determination
8. CHY 323 Pericyclic Reactions and Reactive intermediates
9. CHY 324 Theoretical Spectroscopy
10. CHY 411 Chemistry of Solids & Materials
11. CHY 412 Chemistry of C-C and C-X Bonds
12. CHY 413 Instrumental Methods
13. CHY 421 Chemistry of s,p and f-block elements
14. CHY 422 Physical Organic Chemistry
15. CHY 423 Advanced Organic Chemistry
16. CHY 424 Electrochemistry and Statistical Thermodynamics

Lab Courses

1. CHY 316 Organic Chemistry Lab
2. CHY 325 Inorganic Chemistry Lab
3. CHY 414 Physical Chemistry Lab

Partial List of Elective Courses

1. Bioinorganic Chemistry
2. X-ray Crystallography and Symmetry
3. Heterocycles, Carbohydrates and Aminoacids
4. Contemporary Methods in Organic Synthesis
5. Inorganic Rings and Cages
6. Computational Chemistry

THEORY COURSES

CHY 111 Atomic Structure and Chemical Bonding [3103]

Atomic Structure: Recap of dual nature of radiation and matter, Bohr theory and Hydrogen atom spectra.

Introductory quantum mechanics for chemistry, quantization of energy and angular momentum, the Schroedinger equation, postulates of quantum theory, understanding of postulates via model problems, particle in a one dimensional box, probabilities and electron density.

Hydrogen atom, separation of variables, quantum numbers, orbitals and nodes. Approximations used for multi electron atoms, effective nuclear charge, Slater's rule and qualitative description of SCF theory.

Chemical Bonding: Molecular symmetry, symmetry elements and classification of molecules to point groups.

General discussions on bonding, valence bond and molecular orbital theory, linear combination of atomic orbitals (LCAO) approach, Hybridization, molecular orbitals, normalization of molecular orbitals, overlap integral.

Bonding and anti-bonding orbitals, bonding in homonuclear diatomic systems, dihydrogen molecule-ion and dihydrogen molecule, homonuclear diatomic molecules of the second period, their energetics, bond orders, bond lengths and bond strengths.

Bonding in heteronuclear diatomic molecules (selected ones), polar bonds, electronegativity.

Photoelectron spectroscopy: Principle and application to simple spectra of diatomic molecules.

HMO theory, π conjugation, delocalization energy. Application of HMO theory to simple conjugated systems and aromaticity.

TEXTBOOKS/REFERENCES

1. P. W. Atkins and Julio de Paula, *Physical chemistry*, 8th Ed., Oxford University Press.
2. D. A. Mc Quarrie, *Quantum chemistry*, 2nd Ed.
3. J. Barrett, *Structure and bonding, Tutorial Chemistry Text*, Royal Society of Chemistry.
4. K. J. Laidler and J. H. Meiser, Physical chemistry, Indian Ed.

CHY 121 Concepts in Inorganic Chemistry [3103]

Periodic Trends in chemical elements: Basis for periodicity; Effective nuclear charge; Screening effect; Size of atoms and ions; Ionization energies; Electronegativity, Electron affinity; Diagonal relationships; Inert pair effect; Lanthanide contraction; Fajan's rules.

Acids and Bases: Various theories of acids and bases; Brönsted acids and bases; Concepts of pH, pKa, pKb as applied in different chemical structures; Acidity and basicity of oxides; Lewis acidity; Hard and soft acids and bases, non aqueous solvents.

Redox Chemistry: Redox potential and stability; Electrode potentials; Nernst equation; Diagrammatic representation of electrochemical data; Applications of redox chemistry in the extraction of elements, corrosion, etc.

Simple Inorganic Solids: Ionic structures; close packing; Radius ratios; Energetics; Structures of NaCl, CsCl, Wurtzite; Solubility of ionic compounds.

Non-metal chemistry: Structures of compounds formed by s and p block elements including structures of elemental B, C, Si, P, S, Ge.

Transition Elements: Coordination compounds; Ligands; Nomenclature; Spectrochemical series of ligands; Crystal field theory; Splitting of d-orbitals in the presence of octahedral, tetrahedral and square planar crystal field; Low-spin and high-spin complexes; Application of CFT to explain color and magnetism in transition metal complexes.

Nuclear Chemistry: Nuclear reactions, fission and fusion, radio-analytical techniques and activation analysis.

TEXTBOOKS/REFERENCES

1. F. A. Cotton, G. Wilkinson and P. L. Gaus, *Basic Inorganic Chemistry*, 3rd Ed. (1995).
2. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic Chemistry: Principles and Reactivity* 4th Ed., Pearson Education, (2008).
3. P. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins, *Inorganic Chemistry* 4th Ed., Oxford University Press (2008).
4. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models in Inorganic Chemistry* 3rd Ed., Wiley (1994).

CHY 211 Basic concepts in organic chemistry [3103]

Use of arrows in organic chemistry, introduction to stereochemistry. Concept of chirality, Fisher projection formula, Newmann projection, and Sawhorse projection sequence rule, R and S notations in cyclic and acyclic compounds, optical isomerism of compounds containing one or more asymmetric carbon atoms, erythro, threo, and meso vs racemic mixture; Conformational analysis of ethane and butane.

Geometrical isomerism-E and Z notation of compounds with one and more double bonds in acyclic systems, inter conversion of geometrical isomers, stereochemistry of other classes of double bonded systems.

Electrophilic addition to the alkenes. Basicity, acidity, pKa.

Reactive intermediates: Formation, structure, stability and fate of various reactive intermediates (carbanion, carbocation).

Nucleophilic substitution at saturated carbons (S_N1, S_N2 and S_Ni): Types, stereochemical consideration, role of solvent, neighbouring group participation.

Elimination reactions: Types (E1, E2 and E1cB), stereochemical consideration, role of solvents, Hofmann rules, Zaytsev Rules, Bredt's rule, nucleophilic addition to the carbonyl group, nucleophilic substitution at

the carbonyl group.

Electrophilic aromatic Substitution: Benzene and its reaction with electrophiles, Effect of functional groups.

Nucleophilic aromatic substitution: via addition elimination and elimination addition; diazonium compounds, benzyne mechanism.

TEXTBOOKS/REFERENCES

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

CHY 221 Principles of Physical Chemistry [3103]

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

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

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

Review of Laws of Thermodynamics: Temperature, Energy and Enthalpy, Entropy, Gibbs Energy and Helmholtz energy, review of Maxwell's relations

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

Gibbs energy of a reaction mixture. Expressing chemical equilibrium in terms of chemical potential, Gibbs free energy changes in chemical reaction, equilibrium constants.

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

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

TEXTBOOKS/REFERENCES

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

CHY 311 Coordination Chemistry [3003]

Bonding in Metal Complexes: Molecular orbitals; σ-type, π-type, δ-type interactions in transition metal complexes; Bonding situation in various geometry complexes.

Electronic Spectra of Metal Complexes: Russell-Saunders symbols; Electronic transitions in metals complexes; Selection rules; Effect of Jahn-Teller distortion; Charge transfer spectra.

Magnetism: Magnetic susceptibility; Magnetic moment; spin orbit coupling; Ferromagnetism and antiferromagnetism; Anomalous magnetic moment; Thermal effects; Single molecular magnets.

Structure and Stability: Geometry of coordination complexes; Isomerism; Optical activity; Thermodynamic and kinetic stability; Chelate effect; Asymmetric synthesis.

Reactions of Metal Complexes: Substitution reactions in in square planar and octahedral complexes; Stereochemical reactions; Electron transfer reactions; Photochemical reactions.

TEXTBOOKS/REFERENCES

1. *Molecular Orbitals of Transition Metal Complexes*, Yves Jean, Oxford University Press, 2005.
2. *Coordination Chemistry*, Joan Ribas Gispert, Wiley-VCH Electronic Absorption Spectroscopy and Related Techniques,
3. D. N. Sathyanarayana, Universities Press, 2001.
4. *Elements of Magnetochemistry*, R. L. Dutta and A. Syamal, Affiliated East-West PVT Ltd, 1993.

CHY 312 Stereochemistry: Principles and Applications [3003]

Molecular symmetry and chirality axis, plane, center and alternative axis of symmetry, atropisomerism, helicity.

Difference between configurations and conformations, factors affecting the stability of conformers, dipole interaction, strain. Conformations, stereochemistry of simple and substituted cyclopentane, cyclohexane, and Decalin.

Diastereoselectivity: Stereoselective reactions, prochirality, diastereoselective addition to carbonyl groups, chelation controlled stereoselectivity,

stereoselective reactions of acyclic alkenes.

Stereoselective synthesis of alkenes: Julia olefination, Peterson elimination, Wittig reaction, HWE reaction, Still-Gennari modification, Shapiro reaction, Mcmurry reaction. Metal-mediated alkene synthesis [Tebbe olefination, Petasis reaction, Heck reaction, Suzuki reaction, metathesis (cross metathesis, enyne metathesis, RCM)], stereoselective addition to alkynes (Birch reduction and Lindlar's O_2 reduction).

TEXTBOOKS/REFERENCES

1. E. L. Eliel, *Stereochemistry of Carbon Compounds*, Tata McGraw-Hill Edition 1975, 38th reprint 2008.
2. D. Nasipuri, *Stereochemistry of Organic Compounds-Principle and Applications*, 2nd Ed., New Age International Publishers, 2007.
3. F. A. Carey and R. J. Sundberg, *Advanced organic chemistry*.
4. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic chemistry*.
5. R. Bruckner, *Advanced organic chemistry, Reaction mechanisms*, Academic Press.
6. Carruthers W.S. *Modern Methods of Organic Synthesis* 3rd edition, Cambridge University Press, 1986.

CHY 313 Quantum Chemistry [3003]

Fundamental Background: Blackbody radiation, photoelectric effect, spectral emissions from atoms, dual nature of light and matter, Schrodinger equation and its analogy with the classical wave equation, postulates of quantum mechanics, wave functions and requirements for an acceptable wave function, operator formalism, eigenfunctions and eigenvalues, expectation values, Hermitian operators, measurement, superposition of states, commuting operators, uncertainty principle.

Exactly Solvable Problems: Free particle, quasi-free particle (1-D, 2-D and 3-D box problems), concepts of quantum numbers and degeneracies, quantum wells and dots, quantum tunneling and scattering, simple harmonic oscillator, particle on a ring, particle on a sphere, angular momentum, hydrogen atom problem, atomic orbitals.

The Variation Method: Rayleigh-Ritz method, application to the solution of helium atom problem, independent electron approximation, Slater

determinants, Pauli principle, LCAO-MO, the H_2^+ molecule-ion, molecular orbitals for diatomic molecules, Huckel theory.

Time-Independent Perturbation Theory: Formal development of non-degenerate perturbation theory upto second order, perturbation treatment of the ground state of helium atom, comparison with the variation treatment, excited states of helium atom.

TEXTBOOKS/REFERENCES

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

CHY 314 Group Theory in Chemistry [3003]

Introduction: Definition of symmetry, symmetry elements and symmetry group. Symmetry elements and symmetry operations in molecules, classes of operations and similarity transformations.

Point group classification: Systematic procedure to determine symmetry point group of molecules.

Matrix representation of symmetry operations, basis vectors, reducible and irreducible representations, characters representations, theorems on characters. Construction of Character Tables for point groups.

Applications:

a) Molecular vibrations: Infrared and Raman spectroscopy.
b) Chemical bonding: Hybridisation in molecules.
c) Molecular orbitals and electronic spectra.
d) Preservation of symmetry in chemical reactions. Woodward-Hoffmann

rules.
e) Group theory and Molecular Complexes. Ligand Field Theory.
f) Symmetry of Crystals: International Notations. Crystallographic Point Groups. Bravais Lattices.

TEXTBOOKS/REFERENCES

1. *Chemical application of group theory*, F.A. Cotton
2. *Group theory in chemistry*, Ramakrishnan V. & M.S. Gopinathan

CHY 315 Chemical Kinetics [3003]

Introductory kinetics: Determination of order of reaction, complex reactions, integration of rate equations, opposing reactions, parallel reactions, and consecutive reactions, methods of analysis, measurement of rates, replacement of time with area variable, the steady state approximation.

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

Reactions in solution: Nature of liquids, effect of pressure, dielectric constant and ionic strength, state-to-state dynamics, molecular beams. Chain reactions: normal and branched chains, explosion reactions, Rice-Herzfeld mechanism.

Fast reaction kinetics: Relaxation methods, large perturbation, flash photolysis, lasers photolysis, pulsed radiolysis, small perturbation. Kinetics in the excited electronic states: Jablonskii diagram, kinetics of unimolecular photophysical and photochemical processes, photoisomerisation, bimolecular photophysical and photochemical processes, excimers, exciplexes and sensitisation; Time scales of photophysical processes, primary quantum yield, photostationary states, mechanism of the decay of singlet excited state and Stern-Volmer equation, resonance energy transfer, light

induced electron transfer and Marcus equation; Laser photochemistry including pulsed laser and multiphoton excitation, laser flash photolysis in various time scales. Kinetics of natural light induced processes including photosynthesis and vision, designing of light induced systems and tuning of their rates, light induced processes and environment.

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

TEXTBOOKS/REFERENCES

1. K. J. Laidler, *Chemical Kinetics*, 3rd Ed., Pearson Education (Indian Ed.).
2. M. R. Wright, *An Introduction to Chemical Kinetics*.
3. J. Rajaram and J. C. Kuriacose, *Kinetics and mechanism of chemical transformation*, Macmillan India.
4. S. K. Upadhyay, *Chemical Kinetics and Reaction Dynamics*, Springer.
5. G. D. Billing and K. V. Mikkelsen, *Introduction to Molecular Dynamics and Chemical Kinetics*.
6. P. Atkins, *Physical Chemistry*, 8th Ed., Oxford University Press.
7. N. J. Turrro, V. Ramamurthy and J. C. Scaiano, University Science Books.
8. J. R. Lakowicz, *Principles of Fluorescence Spectroscopy*, 3rd Ed., Springer.

CHY 321 Organometallics and Bioinorganic Chemistry [3003]

Introduction: Definition of organometallic compounds; Historical perspective; Significance of valence electron count.

Organo-Transition Metal Chemistry: Synthesis structure and reactivity of organometallic compounds bearing carbon monoxide, phosphines, alkyls, aryls, conjugated hydrocarbons, carbenes and hydrides.

Organometallic Catalysis: Alkene metathesis; Olefin hydrogenation; Olefin polymerization; Olefin oxidation; Hydroformylation; Fischer-Tropsch process; Carbon-carbon bond forming reactions; Methanol carbonylation.

Biological functions of inorganic elements in organisms: Occurrence, availability, Biological ligands for metal ions; Function and transport of K^+, Na^+, Ca^{2+} and Mg^{2+} ions in biological systems; Complexes of alkali and alkaline earth metal ions with macrocycles; Ion channels; Ion

pumps.

Photosynthesis and O_2 Transport: Tetrapyrrole ligands and other macrocycles; Metals in the centre of photosynthesis-Mg and Mn; Photosynthetic process; Mn-catalysed oxidation of water to O_2; Cobalamines including vitamin and coenzyme B_{12}; Haemoglobin and myoglobin and their functions; Cooperative effect in haemoglobin; Perutz mechanism; Haemerythrin and haemocyanin.

Cytochromes, Fe and Cu-containing proteins: Cytochrome P-450 and oxygen transfer from O_2 to non-activated substrates; Catalases and peroxidases; Generation and function of organic free radicals; Uptake, transport and storage of iron, Fe-S and other non-heme iron proteins; Ferredoxins, transferrin, ferritin; Type 1 blue copper centres; Type 2 and type 3 copper centres in O_2-activating proteins.

TEXTBOOKS/REFERENCES

1. *Basic Organometallic Chemistry: Concepts, Syntheses and Applications* B.D. Gupta, Anil J. Elias, Universities Press (2013)
2. *Organometallics*, Christoph Elschenbroich, Wiley-VCH (2006)
3. *Organotransition Metal Chemistry: From Bonding to Catalysis*, John Hartwig, University Science Books (2010)
4. B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models if Inorganic Chemistry*, 3rd Ed., Wiley (1994).
5. W. Kaim and B. Schwederski, *Bioinorganic chemistry: Inorganic Elements in the Chemistry of Life*, Wiley (2006).
6. S. J. Lippard and J.M. Berg, *Priniciples of Bioinorganic Chemistry*.

CHY 322 Methods in Structure Determination [3003]

Nuclear Magnetic Resonance spectroscopy: Principle of NMR, common spin 1/2 nuclei, Zeeman splitting, Boltzmann distribution, effect of magnetic field strength on sensitivity and resolution, ^{1}H-NMR, chemical shift, anisotropic effects, chemical and magnetic equivalence, coupling constants, applications: Karplus relationship of J on dihedral angle, first order J splitting patterns and structure correlation, strong coupling effects, ^{13}C satellites, ^{13}C-NMR, natural abundance, sensitivity, ^{13}C chemical shifts and structure correlations. DEPT pulse sequences, 2D NMR; ^{1}H COSY, one-bond (HSQC) and multiple-bond (HMBC) ^{1}H–^{13}C correlations. Defining molecular stereochemistry using the Nuclear Overhauser

effect (NOE), dynamic processes by NMR, restricted rotation, cyclohexane ring inversion.

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

Mass Spectrometry: Ionization methods, mass analyzers, fragmentation patterns (Mclafferty rearrangement), interpretation of EI mass spectra. Qualitative mass spectrometry analysis: Chemical formulae calculation; nitrogen rule; high resolution analysis of isotopes signatures. Illustrative examples of structure elucidation from spectra.

TEXTBOOKS/REFERENCES

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

CHY 323 Pericyclic Reactions and Reactive intermediates [3003]

Pericyclic reactions: Four classes of pericyclic reactions, Woodward-Hoffmann rules in (i) cycloaddition (thermal and photochemical condition 4+2, 2+2) (ii) electrocyclic reactions (iii) sigmatropic reactions (iv) group transfer reactions with examples. Woodward-Hoffmann rules, frontier orbitals, and orbital symmetry correlation diagrams examples. Diels-Alder reaction-endo/exo-regioselectivity, effect of Lewis acid on Diels-Alder reaction; electrocyclic reactions-Claisen, Cope with stereochemistry; group transfer reactions-ene reaction; and, 1,3 dipolar cycloaddition including

ozonolysis and reaction of ketene with alkenes.

Photochemical reactions: Paterno-Buchi reaction, photodimerization of alkenes. Photochemical reactions of carbonyl compounds: Norrish type I and II reactions, di-pi methane rearrangement.

Carbenes and Nitrenes: Structure of carbenes, generation-addition and insertion reactions, carbene based rearrangements. Structure of nitrene generation and reaction-electron deficient nitrogen intermediates, and rearrangements (Curtius, Schmidt and Beckmann).

Radicals: Generation of radical intermediates-addition to alkenes, alkynes (inter and intramolecular) to form C–C bonds-Baldwin's rules-fragmentation and rearrangements. Named reactions involving radical intermediate–Barton deoxygenation and decarboxylation–Ketyl radicals-synthesis of pinacol.

TEXTBOOKS/REFERENCES

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

CHY 324 Theoretical Spectroscopy [3003]

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

Introduction to Molecular Spectroscopy: Molecular Hamiltonian, Born-Oppenheimer approximation. Nuclear motion in diatomics, separation of translational and relative motion. Rotational spectroscopy: Rotation of rigid bodies, moment of inertia, linear molecules, spherical, symmetric

and asymmetric tops, selection rules, rotational spectra and line intensities, molecule and space fixed coordinate systems, structure determination from rotational constants, isotopic effects.

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

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

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

NMR & EPR: Expression for Hamiltonian/Energy - Zeeman interaction, torque exerted by a magnetic field on spins, equation, its solution and the physical picture of precession. Thermal equilibrium, Curie susceptibility. Expressions for MR spectral sensitivity. Approach to equilibrium, Bloch equations, the rotating frame, pulsed experiments, solutions of classical master equation.

Density matrix approach and product operator formalism for NMR, spin Hamiltonian, isotropic and anisotropic interactions, Vector description of simple NMR experiments like INEPT, DEPT.

EPR Hamiltonian, theory of g-factors in EPR, theory of hyperfine interactions in π-type free radicals.

TEXTBOOKS/REFERENCES

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

CHY 411 Chemistry of Solids and Materials [3003]

Structures of Solids: Crystal structures-Symmetry in crystals: Crystallographic point groups, space groups, lattices, one and two dimensional unit cells, translational symmetry elements, three dimensional unit cells, Miller indices, inter-planar spacings, packing diagrams. Close packing, body centered and primitive structures.

Ionic Solids: Ionic solids with formula MX (CsCl, NaCl, NiAs, Zinc Blende and Wurtzite Structures), MX_2 (Fluorite and Antfluorite Structures, Cadmium Halides, Rutile, Anti-rutile, beta -cristobalite), other crystal systems (Bismuth tri-iodide, Corundum, Rhenium Trioxide etc.), Mixed oxides (Spinel, Perovskite, Ilmenite).

Non Ionic Solids: Covalent solids, molecular solids and dispersion interactions, Pauling rules, silicates, phosphates, arsenates and related extended systems, zeolites, mesoporous materials, clay, metal-organic and related open framework materials, hybrid materials.

Defects and Dislocations in Solids: Point defects, dislocations, geometrical representation of various types, grain boundary, phase boundary, examples in alloys and materials.

Synthesis of Solids: Theory of nucleation and crystal growth, Phase transitions. Gas to Solid Synthesis: Vapour deposition, chemical vapour deposition (CVD/MOCVD), sputtering. Liquid to Solid Synthesis: Crystal growth from melt, liquid quenching, sol-gel methods, ion-exchange and intercalation. Solid to Solid Synthesis: Solid state reactions, high pressure

synthesis, glass, ceramics. Other Methods: Microwave reactions, combustion synthesis, hydrothermal methods and high temperature superconductors.

Electronic Structure of Solids: Free electron theory, Drude model, concept of Fermi level, density of states, band structure, direct and indirect band gaps, the Hall effect, band structure for some simple solids, electronic structure of metals and alloys, Fermi Surface, Analysis of Bands, Partial density of states (PDOS) and crystal orbital overlap population (COOP). Intrinsic, extrinsic semiconductors. Basic ideas of superconductivity.

Magnetic Properties of Solids: Magnetization, types of magnetic materials, Langevin diamagnetism, order-disorder transitions, mean field approximation, Curie law and Curie-Weiss law, band electron theory for magnetism, Pauli paramagnetism, exchange coupling, spin-up and spin-down half bands, band model for transition metal alloys, the localized electron model for magnetism (lanthanides), mean field approximation, giant, tunneling and colossal magnetoresistance.

Dielectric Properties of Solids: Electrical polarization, dielectric constant, piezoelectric crystal, quartz, ferroelectric effect, multilayer ceramic capacitor, photovoltaics.

Other novel materials: Carbon nanostructures (Fullerenes, carbon nanotubes and graphenes) Structure and properties. Glasses and amorphous solids, Thin films, Polymers, Nanomaterials, Ionic-superionic conductors and high Tc Superconductors.

TEXTBOOKS/REFERENCES

1. A. R. West, *Solid State Chemistry*, Wiley Student Ed., (2014) (Indian Ed.).
2. C. N. R. Rao and J. Gopalakrishnan, *New Directions in Solid State Chemistry*, 2nd Ed., Cambridge University Press (1987).
3. L. E. Smart and E. A. Moore, *Solid State Chemistry: An introduction*, 3rd Ed., Taylor and Francis, 2010 (Indian Ed.)
4. P. A. Cox, *The Electronic Structure and Chemistry of Solids*, Oxford Science Publications (1987).

5. D. Jiles, *Introduction to the Electronic Properties of Materials*, 2nd Ed., (2010), Nelson Thornes Ltd. (Indian Ed.)
6. G. Gottstein, *Physical Foundations of Materials Science*, Springer (2004).
7. R. Hoffmann, *Solids and Surfaces: A chemist?s view of bonding in extended structures*, Wiley-VCH, 1988.
8. N. W. Ashcroft and N. D. Mermin, *Solid State Physics*, Brooks-Cole (1976).
9. S. Elliot, *The Physics and Chemistry of Solids*, Wiley India (1998).

CHY 412 Chemistry of C–C and C–X Bonds [3003]

Keto-enol tautomerism: formation of enols by proton transfer, enolization catalysed by acids and bases.

Alkylations of metal enolates including boron. Alkylation of carbonyl compounds, alkylation of active methylene compounds, C-alkylation vs O-alkylation, generation of thermodynamic vs kinetically controlled enolates. Alkylation via dianion. Generation and reactions of enamine.

Aldol reaction; diastereoselective aldol reaction, Mukaiyama aldol reaction. Intramolecular aldol reactions, and Robinson annulation. Crossed Claisen ester condensations, Dieckmann condensation, Knoevenegal, Stobbe, Darzen, Acyloin condensations, Henry reaction, Mannich reaction.

Michael addition; 1,2 *vs* 1,4-addition, conjugate addition followed by alkylation, conjugate substitution reactions (Baylis-Hilmann reaction, nucleophilic epoxidation), conjugate addition of organometallic reagents.

TEXTBOOKS/REFERENCES

1. F. A. Carey and R. J. Sundberg, *Advanced organic chemistry*.
2. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic chemistry*.
3. R. Bruckner, *Advanced organic chemistry, Reaction mechanisms*, Academic Press.

CHY 413 Instrumental Methods [4004]

Basics of measurement: Separation Techniques: Separation based on increasing number of factors (volatility, solubility, interactions with stationary phase, size, electrical field), gas and liquid chromatography, elec-

trophoresis (plates and capillary).

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

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

X-ray Crystallography: Principles, concepts of symmetry, point groups and space groups; crystal lattices, elements of scattering theory, diffraction principles, structure factor, fourier transform, phase problem in crystallography, reciprocal lattice.

Powder diffraction: Single crystal methods; Data collection and processing strategies; Patterson and direct methods; Refinement techniques, Rietveld refinement in powder diffraction, particle size determination from powder X-ray data, Synchrotron radiations usage, Small angle X-ray scattering, Basics of neutron diffraction, electron diffraction.

TEXTBOOKS/REFERENCES

1. C. Giacavazzo (Ed.) *Fundamentals of crystallography*.
2. J. D. Dunitz, *X-ray analysis and the structure of organic molecules*.
3. G.H. Stout and L.H. Jensen, *X-ray structure determination: A practical guide*.
4. A. R. West, *Solid State Chemistry*, Wiley Student Edition, 2003.
5. R. S. Drago, *Physical Methods in Inorganic Chemistry*.
6. D. A. Skoog, F. J. Holler and T. A. Nieman, *Principles of Instrumental Analysis*, 5th Ed., Brooks Cole.
7. H. Willard, L. Merritt and J. Dean, I *nstrumental Methods of Analysis*, 7th Ed., Wadsworth Publishing Company.
8. Banwell, *Fundamental of Molecular Spectroscopy*.

CHY 421 Chemistry of s, p and f-block elements [3003]

s-block elements: Dinitrogen compounds; Metallic hydrides; Compounds of alkali metals; Alkali metal solutions in liquid ammonia, Zintl compounds, Crown ether and cryptand complexes; Organolithium compounds, Compounds of alkaline earth metals; Anomalous properties of beryllium; reactivity of s-block elements.

p-block elements
Group 13 elements: Boron halides; Diborane-electron deficient compounds; Boranes and boron clusters; Wade's rules, Carboranes and metalloboranes; Borazines and boron nitride, organoboron and organoaluminium compounds.

Group 14 elements: Carbides; Silicates; Aluminosilicates; Organo compounds of silicon, tin and lead.

Pnictogens: Nitrogen activation; Oxides of nitrogen and phosphorus; Pnictogen halides; Phosphazenes, rings and clusters.

Chalcogens: Oxo-acids of sulphur, Polyanions of sulfur, selenium, and tellurium; sulphur-nitrogen & phosphorus based compounds.

Halogens: Pseudohalogens; Polyhalides; Structure and bonding in interhalogen compounds; Oxoacids and oxoanions of halogens; Fluorocarbons; CFC's and ozone layer.

Nobel Gases: Structure and bonding in halides and oxo-halides of xenon compounds.

f-block elements: Lanthanide contraction; Occurrence and recovery; Separation of Lanthanides; electronic spectra and MRI contrast agents.

TEXTBOOKS/REFERENCES

1. *Advanced Inorganic Chemistry*: F.A. Cotton, G. Wilkinson, C.A. Murillo and M. Bochmann (1999) 6th edition, Wiley-Interscience
2. *Inorganic Chemistry*: D. Shriver and P. Atkins (2006) International Student Edition, 4th edition, Oxford University Press

3. *Basic Inorganic Chemistry*, F. A. Cotton, G. Wilkinson and P. L. Gaus, 3rd Ed. (1995).
4. *Concepts and Models in Inorganic Chemistry*, B. Douglas, D. McDaniel and J. Alexander, 3rd Ed., Wiley (1994).
5. *Chemistry of Elements*, N. N. Greenwood and Alan Earnshaw, 2nd Ed, Elsevier 1997.

CHY 422 Physical Organic Chemistry [3003]

Molecular Structure and Thermodynamics: Introduction to Structure and Models of Bonding, Strain and Stability, Solutions and Non-Covalent Binding Forces, Molecular Recognition and Supramolecular Chemistry.

Acid Base Chemistry, Stereochemistry; Reactivity, Kinetics, and Mechanisms: Energy Surfaces and Kinetic Analyses, Experiments Related to Thermodynamics and Kinetics, Catalysis, Organic Reaction Mechanisms, Hammett Plot-LFET, QSAR, Organotransition Metal Reaction Mechanisms and Catalysis, Organic Polymer and Materials Chemistry; Electronic Structure, Theory and Applications: Advanced Concepts in Electronic Structure Theory, Electronic Organic Materials.

TEXTBOOKS/REFERENCES

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

SUPPLEMENTARY READING:

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

CHY 423 Advanced Organic Chemistry [3003]

Heteroatoms in organic synthesis: Sulfur: Sulfur stabilized anions, sulfonium salts, sulfonium ylides, sulfur stabilized cations, sulfoxides, oxi-

dations using selenium. Boron: organoboron reagents and reactions; Silicon: Organosilicon compounds and their reactions, organotin compounds and their applications. Important catalyzed reactions such as palladium catalyzed reactions including Heck, Stille, Sonogashira, Kumada, Suzuki & Negishi, alkene metathesis, enyne metathesis.

Metal mediated oxidations: Non-metal mediated oxidations: eg. Swern oxidation, IBX, Stereo- and enantioselective oxidation reactions: Reduction with metal hydrides: Dissolved metal based reduction: eg. Birch reduction. Catalytic hydrogenation reactions: Stereo-and enantioselective reductions: Functional group interconversion, common catalysts and reagents (organic, inorganic, organometallic and enzymatic, chemoselectivity. Use of protecting groups in multi-step synthesis: Different protection and deprotection methods.

Retrosynthetic analysis: Synthesis backwards, disconnections, synthons, choosing disconnections, functional group interconversion, two group disconnections, C–C disconnections, donor-acceptor synthons, natural reactivity and umpolung. Synthesis: Illustrative synthesis of complex natural products with relevant examples.

TEXTBOOKS/REFERENCES

1. F. A. Carey and R. J. Sundberg, *Advanced organic chemistry*.
2. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic chemistry*.
3. Warren S. *Organic Synthesis: The Disconnection Approach*, Wiley, NY, 1982.
4. Wyatt P. and Warren S, *Organic Synthesis*, Strategy and Control; Wiley 2007.
5. Carruthers W. S., *Modern Methods of Organic Synthesis* 3rd edition, Cambridge University Press, 1986.
6. House, *Modern Synthetic Reactions*, 1972.?
7. *Greene's Protective Groups in Organic Synthesis*, A John Wiley & Sons publications, 2007.
8. L. Kurti and B. Czako, *Strategic Applications of Named Reactions in Organic Synthesis*, Elsevier Academic Press, 2005.
9. R. Bruckner, *Advanced organic chemistry, Reaction mechanisms*, Academic Press.

CHY 424 Electrochemistry and Statistical thermodynamics [3003]

Electrochemistry as interdisciplinary Science, Electrochemistry and Battery Technology, Electrochemical approaches to environmental problems.

Ionics: True and potential electrolytes, ion-solvent interactions –solvation of salts, size and structure of solvation shell, solvation number, IR, NMR, X-ray and neutron diffraction methods to study hydration of salts.

Ion-Ion interactions: Debye-Hckel (or Ion-Cloud) theory, activity coefficients, theoretical estimation of activity coefficients, Triumphs and limitations of Deby-Hckel law, Extended Deby-Hckel law based on finite size ion model, Bjerrum ion-pair formation, ion pairs to triplet ions to cluster of ions.

Electrodics: Overpotentials, Exchange current density, Derivation of Butler-Volmer equation and its implications, Tafel plot, Multistep electrode reactions, Determination of multistep electrode reactions, Mass transfer by diffusion, Charge transfer at electrode-solution interfaces, Quantization of charge transfer, Tunneling, Structure of double layer at semiconductor-solution Interface.

Electrochemical Methods: Controlled potential and current techniques, Hydrodynamic techniques, Electrochemical instrumentations, Scanning probe techniques.

Statistical Thermodynamics: Concepts of statistical thermodynamics. Micro canonical, canonical and grand canonical ensembles. Ensemble averages. Most probable distribution. Boltzmann statistics, Fermi-Dirac statistics and Bose-Einstein statistics. Ideal monatomic, diatomic and polyatomic gas.

Partition functions: Equilibrium constant in terms of partition functions, Debye-Huckel theory, Statistical mechanics of ionic solutions, Flory-Higgins theory of polymer solutions, Specific heats of solids- Einstein and Debye models, Virial equation of state and virial coefficients, law of corresponding states.

TEXTBOOKS/REFERENCES

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

SUPPLEMENTARY READING:

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

CHY 3201 Computational Chemistry [3003]

Mathematical preliminaries and physical concepts for Classical and Quantum mechanics:Concepts of Force Field, Equilibrium, Transition state, Translational, vibrational and rotational motions. Classical Newtonian and Quantum mechanical equations of motion.Vector spaces, coordinate systems, Matrix algebra, Eigen value problems, Solution of first and second order differential equations. [6 hrs]

Molecular Mechanics (MM) and Molecular Dynamics (MD). Molecular structure through classical force fields. Energy minimization methods. MD simulation of large molecules: Calculation of thermodynamic properties; Protein folding, Molecular docking and drug interaction. [6 hrs]

Quantum mechanics of atoms and molecules. Hartree-Fock theory. Solution of HF equations for atoms and molecules. Gaussian basis sets. Beyond Hartree-Fock. Configuration Interaction; Perturbation theory: Coupled Cluster theory. [8 hrs]

Density Functional Theory(DFT): Introduction to functions and functionals. Thomas Fermi and Slater X-alpha density functionals. Hohenberg-Kohn theorem. Kohn-Sham equations and solutions. Improved functionals. [6 hrs]

Ab initio molecular dynamics with DFT. Car-Parrinello method and applications to reaction dynamics, solution structures ,large biomolecules, self-assembled nano systems. [2 hrs]

Calculation of spectroscopic, magnetic and electric properties of molecules and solids using the above theoretical tools. [8 hrs]

TEXTBOOKS/REFERENCES

1. A. Szabo and N.S.Ostlund, Modern Quantum Chemistry: Introduction to Advanced electronic Structure Theory, Dover,1996.
2. W. Koch and M.C. Holthausen, A Chemists guide to Density Functional Theory, Viley-VCH, 2001.
3. D.S. Sholl and J.A. Steckel, Density Functional Theory: A Practical Introduction. Wiley, 2009.
4. T. Heine, J.O. Joswig and A. Gelessus, Computational Chemistry Workbook, Wiley-VCH, 2009.
5. E. G, Lewars , Introduction to the theory and applications, Springer, 2011

CHY 3202: Heterocycles, Carbohydrates and Aminoacids [3003]

Heterocycles: Saturated heterocycles: Introduction, reaction of heterocycles, conformation of saturated heterocycles, anomeric effect, ring closing reactions to make heterocycles; Aromatic heterocycles: pyrroles, thiophenes, furans, pyridines, pyrazoles, pyridazines, pyrimidines, isoxazoles, tetrazoles, quinolines, isoquinolines, Fischer Indole synthesis; carbohydrates.

Carbohydrates: Monosaccharides-classification, osazone formation, stepping up and stepping down of aldoses, interconversion of aldoses to ketoses and vice versa, epimerisation. Constitution and configuration of D-glucose and D-fructose, ring structure and conformational aspects of D-glucose and its derivatives, anomeric effect, mutarotation of D-glucose. Amino acids: Synthesis of α-amino acids (Gabriel, Strecker, azlactone, acetamido, malonic ester methodologies). Isoelectric point, ninhydrin reaction, resolution of amino acids. Peptides: geometry of peptide linkage, peptide synthesis including Merrifield synthesis, structure determination of peptides, C-terminal and N-terminal unit determination, determination of amino acid sequence.

TEXTBOOKS/REFERENCES

1. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic chemistry*.
2. Morrison and Boyd, *Organic Chemistry*, Prentice-Hall of India, 2002.

CHY 4101 Bioinorganic Chemistry [2002]

The reactivity of coordination complexes of metal ions will be discussed in the context of the reaction mechanisms of specific metalloenzymes. A portion of the course will be devoted to the toxicity of metals and also their utility in drugs and in diagnostic agents.

Cytochromes: Cytochrome P-450 and oxygen transfer from O_2 to non-activated substrates. Catalases and peroxidases. Generation and function of organic free radicals. Nitrogen fixation.

Mo and Zn-containing proteins: Mo-containing enzymes. Zinc in biological systems, metalloenzymes. Zinc-finger and other gene regulatory Zn-proteins.

Biomimetic chemistry: Model compounds. Metalloporphyrins, picket-fence porphyrins, capped porphyrins.

Bio-mineralization. Biological functions of the non-metallic inorganic elements. Bioinorganic chemistry of the quintessentially toxic metals. Chemotherapy with compounds of some non-essential elements. Cis platin and its mode of action. Gold-containing drugs. Photodynamic therapy.

ESR and Mossbauer spectroscopy. Characterization of biological systems with these techniques.

TEXTBOOKS/REFERENCES

1. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic Chemistry: Principles and Reactivity*, 4th Ed., Pearson Education, (2008).
2. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Shriver and Atkins *Inorganic Chemistry*, 4th Ed., Oxford University Press (2008).
3. J. D. Atwood, *Inorganic and Organometallic Reaction Mechanism*, 2nd Ed., Wiley-VCH (1997).
4. W. Kaim and B. Schwederski, *Bioinorganic chemistry: Inorganic Elements in the Chemistry of Life*, Wiley (2006).
5. I. Bertini, H.B. Gray, J.S. Valentine and J. Lippard, *Bioinorganic Chemistry*, South Asian Edition, (2007) Viva Books Private Ltd.
6. H.B. Gray, E.I. Stiefel, J.S. Valentine and I. Bertini, *Biological Inorganic Chemistry*: Eds: (2006) University Science Books.

CHY 4102: Contemporary Methods in Organic Synthesis [3003]

Determination of enantiomeric and diastereomeric excess. Desymmetrization, kinetic resolution reactions. Chiral pool approach, acyclic stereoselection: reactions at α-and β-positions of a chiral center.

Asymmetric oxidation [epoxidation Sharpless, Jacobsen, Shi),di hydroxylation (Sharpless)], reduction (Noyori, Corey, Pfaltz), Organocatalyzed asymmetric synthesis.

Stereoselective aldol reactions. Auxillary controlled stereoselection: Evans oxazolidones, Oppolzer sultams, Myers amides, Enders RAMP/SAMP, Shollkopf. Enantioselective alkylation allylation and crotylation reactions.

Common named reactions and rearrangements-applications in organic synthesis.

TEXTBOOKS/REFERENCES

1. E. L. Eliel, *Stereochemistry of Carbon Compounds*, Tata McGraw-Hill Edition 1975, 38th reprint 2008.
2. D. Nasipuri, *Stereochemistry of Organic Compounds-Principle and Applications*, 2nd Ed., New Age International Publishers, 2007.
3. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic chemistry.*
4. F. A. Carey and R. J. Sundberg, *Advanced organic chemistry*.
5. L. Kurti and B. Czako, *Strategic Applications of Named Reactions in Organic Synthesis*, Elsevier Academic Press, 2005.
6. R. Bruckner, *Advanced organic chemistry, Reaction mechanisms*, Academic Press.

LABORATORY COURSES

CHY 112 Chemistry Lab I [0031]

1. Qualitative inorganic salt analysis containing two anions and two cations (5 mixtures)
2. Inorganic preparations: (a) Preparation of potash alum from scrap aluminium (b) Preparation of hexamine Ni(II) chloride (c) Preparation of tetramine Cu(II)sulphate

3. Organic preparations: (a) Preparation of paracetamol (b) Preparation of aspirin
4. Introduction to Chromatography: (a) Separation of metallic ions using paper chromatography (b) Separation of plant extracts using thin layer chromatography
5. Introduction to colorimetry using photoelectric colorimeter: (a) Estimation of iron (b) Estimation of chromium (c) Estimation of nickel and (d) Estimation of phosphate in cola drinks
6. Introduction to titrimetric analysis (acidimetry and alkalimetry): Estimation of antacid capacity of antacid

CHY 122 Chemistry Lab II [0031]

1. Permanganometry: (a) Estimation of hydrogen peroxide, nitrite and checking the purity of potassium nitrate (b) Estimation of Calcium.
2. Dichrometry: (a) Estimation of ferrous and ferric iron using N-Phenyl anthranilic acid indicator (b) Estimation of Zinc using potassium ferrocyanide.
3. Iodometry: (a) Estimation of barium (b) Estimation of copper (c) Estimation of dissolved oxygen and (d) Estimation of available chlorine in bleaching powder
4. Iodimetry: Estimation of ascorbic acid in fruit juice.
5. Argentometry: (a) Estimation of chloride ion using Morh's and Volhard's methods (b) Estimation of potassium bromide using adsorption indicator.
6. Complexometry: (a) Estimation of calcium in milk powder (Eriochrome black T indicator) (b) Estimation of hardness of water (Eriochrome black T indicator) (c) Estimation of calcium and magnesium using Patton and Reeders indicator (d) Estimation of copper using fast sulphon black indicator (e) Estimation of zinc and magnesium using (Eriochrome black T indicator) (f) Estimation of nickel using Eriochrome black T indicator and murexide indicator.
7. Gravimetric Analysis: (a) Estimation of barium/sulphate as barium sulphate (b) Estimation of iron as ferric oxide.

CHY 212 Chemistry Lab III [0031]

1. Determination of melting and boiling points.

2. Purification of organic compounds by crystallization.
3. Identification of organic functional groups (5 compounds).
4. Single stage preparations including nitration, acetylation, benzoylation, bromination, oxidation etc.
5. Two stage preparations: (a) conversion of acetanilide to p-bromoaniline (b) conversion of acetanilide to p-nitroaniline (c) conversion of nitrobenzene to m-nitroaniline.
6. Organic estimations: (a) Estimation of phenol/ aniline (b) Estimation of glucose (c) Estimation of ester (d) Saponification value of oil (e) Iodine value of oil.

CHY 222 Chemistry Lab IV [0031]

1. Phenol water system:
   Determine the mutual solubility curve of phenol and water and hence the consolute point.
   Determine the critical solution temperature of phenol and water in presence of (i) 1% of sodium chloride (ii) 0.5% of naphthalene and (iii) 1% succinic acid. Determination concentration of aqueous solution of KCl by study-ing mutual solubility of phenol and water.

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

3. Solid liquid equilibrium:
   Determination of molal depression constant of naphthalene Determination of molecular weight of solute

4. Transition temperature:
   Determination of transition temperature of a salt hydrate

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

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

6. Chemical kinetics
   Clock Reaction: Study of clock reaction and determination of the factors affecting a reaction
   Determination of the rate constant of hydrolysis of methyl acetate catalyzed 0.5M hydrochloric acid
   Determination of the rate constant of the hydrolysis of ester by sodium hydroxide reaction

7. Conductometric titration
   Conductometric titration of Strong acid$><$ Strong base
   Strong acid $><$ Weak base Weak acid $><$ Strong base Precipitation titration

8. Estimation using conductometric titrations
   Mixture of hydrochloric acid and acetic acid Mixture of hydrochloric acid and oxalic acid Mixture of acetic acid and oxalic acid
   Mixture of sulphuric acid, acetic acid and copper sulphate

CHY 315 Advanced Organic Chemistry Laboratory [0093]

1. Separation and quantification of ternary mixtures: (a) Determination of purity by melting points and TLC. Mixtures No. 1-4
2. S_N1 and S_N2 reactions
3. (a) Determination of moisture content in the organic solvents using Karl-Fischer titration
   (b) Drying of organic solvents
4. Estimation of nitrogen in the given organic compound by Kjeldahl's method

5. Extraction of eugenol from cloves by steam distillation
6. Cycloaddition reaction: Diels-Alder reaction of furan and N-phenylmaleimide, preference for endo or exo-product formation
7. (a) Claisen-Schimidt reaction- Preparation of benzal acetophenone
   (b)Malonic ester synthesis- cyclobutane carboxylic acid
8. Multistage preparations and spectroscopic characterization
   (a) Conversion of bromobenzene to triphenyl carbinol and then to tritylchloride
   (b) Preparation of vanilline and its derivatives from p-hydroxybezaldehyde
   (c) Benzaldehyde to methylstyrene and to 1-phenyl 1,2-dihydroxypropane
   (d) Preparation of benzotriazole from o-nitroaniline
   (e) Preparation of sys-tribromobenzene from aniline
   (f) Validity of Huckel's 4n+2 rule: Synthesis of triphenyl methyl fluoroborate and tropyllium iodide
   (a) Chemiluminesence: Synthesis of cyalume and chemiluminescence

9. Molecular rearrangement:
   (a) Green photochemical reaction (Photoreduction of benzophenone to benzopinacol and then to benzopinacolone)
   (b) Rearrangement of diazoaminobenzene to p-aminoazobenzene
   (c) Benzil Benzilic acid rearrangement
   (d) Preparation of caprolactum from cyclohexanone and nylon-6

10. Ionic liquids:
    Preparation of tetrabutylammonium tribromide (TBATB) and Bromination of Chalcone
    Preparation of 1-pentyl-3-methylimidazolium bromide (pmIm) and Preparation of 2-phenylbenzothiazoles catalyzed by ionic liquid.

11. Phase transfer catalyst:
    Wittig reaction: Preparation and purification of trans-stilbenes

12. Microwave oven assisted organic syntheses
13. Multi-step synthesis coenzyme catalyzed synthesis of Benzoin and derivatives
    Part 1: Synthesis of Benzoin
    Part 2: Synthesis of Benzil
    Part 3: Synthesis of Benzilic Acid

Part 4: Synthesis of Benzoic acid from Benzaldehyde

CHY 325 Advanced Inorganic Chemistry Laboratory [0093]

1. Synthesis and magnetic properties of tetragonal Ni(II) complexes
2. Synthesis of Co(III) complexes and characterization
3. Microwave assisted synthesis of 5,10,15,20 - tetraphenylporphyrin
4. Synthesis and characterization of an oxygen-carrying Cobalt complex which mimics Haemoglobin
5. Binding of a small molecule to a Metalloprotein: Determination of the Equilibrium Binding Constant
6. Reduction potential of cytochrome C
7. Common geometries of pentacoordinate complexes: preparation of acetylacetonate complexes
8. Determination of spectrochemical order of a series of ligands in Ni(II) coordination compounds using electronic spectroscopy.
9. Probing ligand symmetry and coordination modes using IR spectroscopy.
10. Probing the fluxional behaviour in coordination compounds using NMR spectroscopy.
11. Isomerism in coordination chemistry (cis-trans, linkage, optical, etc, kinetics of isomerisation) in Co(II) coordination compounds, effect of ligands and coordination number on the spin states of the transition metal ions in the coordination compounds - measuring the magnetic susceptibility using Gouy's method.
12. Organometallic synthesis of double decker complexes, preparation of Ferrocene and its reactions.
13. Catalysis using polyoxometalates, Probing the redox reactions of multivalent transition metal coordination compounds using electrochemical probes and magnetism.
14. Synthesis and characterization of High Tc superconductor materials.
15. Understanding the structure of simple cubic metal organic frameworks using PXRD.

CHY414 Advanced Physical Chemistry Laboratory [0093]

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

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

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

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

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

6. Spectrophotometry:
   (a) Test the validity of Beer-Lambert's law
   (b) Determination of composition of binary mixture of $KMnO_4$ and $K_2Cr_2O_7$
   (c) Determination of dissociation constant of weak acid/ weak base
   (d) Study the complex formation between Fe(III) and salicylic acid, and find the formula and stability constant of the complex
   (e) Investigate the complex formation of (a) Fe(III) and thiocyanate (b) Ni(II) and ethylenediamine by Job's method

7. Dipole measurement:
   (a) Determination of dipole moment of liquids and variation of dipole moment with temperature

8. Equilibrium and dissociation constant:
   (a) Determination of equilibrium constant of keto-enol tautomerisation of ethyl acetoacetate
   (b) Determination of equilibrium constant of esterification reaction between acetic acid and ethanol.
   (c) Determine the equilibrium constant of the reversible reaction

   $2Ag(I) + CaSO_4) \Rightarrow Ag_2SO_4 + Ca^{2+}$

9. Chemical Kinetics:
   (a) Study the kinetics of iodination of acetone by (a) Visual (b) Titrimetric and (c) Spectrophotometric methods
   (b) Electrochemistry

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

11. Transport number:
    Determination of transport number by moving boundary and Hitroff methods

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

13. Surface Chemistry:
    Adsorption of oxalic acid/ acetic acid on charcoal and verification of Freundlich and Langmuir's adsorption isotherms

14. Fuel Cells:
    Determination of Faraday efficiency and Energy efficiency

15. Corrosion:
    Determination of rate of corrosion of a material at different conditions

16. Concept of particle in a box:
    Determination of C = C length from absorption spectra of conjugated dienes.

17. Electronic potential energy surfaces:
    Absorption spectra of molecular iodine, calculation of vibrational frequencies, anharmonicities and bond energies.

18. Polarimetry:
    (a) Rate constant of hydrolysis of cane sugar
    (b) Determine the percentage of two optically active substances in a given solution

19. Dissociation equilibria of ampholites and determination of isoelectric point

Mathematics Syllabus

MAT 111 Single Variable Calculus [3103]

Properties of real numbers, the least upper bound and the greatest lower bound properties.

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

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

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

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

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

TEXTBOOKS

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

REFERENCES

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

MAT 121 Introduction to Algebra [3103]

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

Group Theory: Definition and examples of groups, finite groups, abelian and cyclic groups, subgroups, functions and permutations, groups of permutations, cycles and cyclic notation, even and odd permutations, the alternating group, example of matrix groups.

TEXTBOOKS

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

REFERENCES

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

MAT 211 Multivariable Calculus [3103]

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

Leibniz's formula, Taylor's formula, Mean Value theorems.

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

TEXTBOOKS

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

REFERENCES

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

MAT 221 Introduction to Probability and Statistics [3103]

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

Random variables and probability distributions: Discrete and continuous distributions and limit theorems: Binomial distribution, geometric distribution, Poisson distribution, normal distribution, exponential distribution,

Gamma distribution, Beta distribution. Cumulative and marginal distribution functions. Transformation of random variables in one and two dimensions.

Mathematical expectations: Expectations for univariate and bivariate distributions, moments, variance, standard deviation, higher order moments, covariance, correlation, moment generating functions, characteristic functions. Central limit theorem, law of large numbers.

Linear Regression.

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

TEXTBOOKS

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

REFERENCES

1. C. M. Grinstead and J. L. Snell, *Introduction to Probability*, 2nd ed., American Mathematical Society, 1997.
2. S. Ross, *A first course in Probability*, 8th ed., Prentice Hall, 2009.
3. S. Ross, *Introductory Statistics*, 2nd ed., Elsevier (India), 2006.
4. K.L. Chung, *Elementary Probability Theory*, 4th ed., Springer, 2003.
5. P. G. Hoel, S.C. Port and C.J. Stone,*Introduction to Probability Theory*, 1st ed, Houghton Mifflin, 1972.
6. W. Feller, *An Introduction to Probability Theory and its Applications*, Volume 1, 3rd ed., Wiley, 2008.
7. W. Feller, *An Introduction to Probability Theory and its Applications*, Volume 2, 2nd ed., Wiley, 2008.
8. R.G. Laha and V. K. Rohatgi, *Probability theory*, Wiley, 1979.

MAT 311 Real Analysis [3003]

Zorn's lemma, Axiom of choice, Metric spaces: Properties and examples, supremum, infimum, neighbourhood, open sets, limit points, Bolzano-Weierstrass theorem, derived sets, closed sets, adherent points, closure of a set, nested intervals, Cantor intersection theorem, cover, open cover,

subcover, Heine-Borel theorem, converse of Heine-Borel theorem, compact sets, connected sets, convergent sequences, subsequences, Cauchy sequences, completeness, continuous functions, continuity and compactness, continuity and connectedness.

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

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

TEXTBOOKS/REFERENCES

1. T. M. Apostol, *Mathematical Analysis*, 2nd Edition, Addison Wesley, 1974.
2. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 4th Edition, Wiley, 2011.
3. R. M. Dudley, *Real Analysis and Probability*, Cambridge University Press, 2002.
4. S. R. Ghorpade and B. V. Limaye, *A Course in Calculus and Real Analysis*, Springer, 2006.
5. R. R. Goldberg, *Methods of Real Analysis*, 2nd Edition, Wiley, 1976.
6. S. Lang, *Undergraduate Analysis*, 2nd Edition, Springer, 1996.
7. W. Rudin, *Principles of Mathematical Analysis*, 3rd Edition, McGraw- Hill, 1976.
8. T. Tao, *Analysis I*, Hindustan Book Agency, 2006.
9. H. L. Royden, *Real Analysis, 3rd Edition,* Phi Learning, 2009.

MAT 312 Abstract Algebra [3003]

Groups, subgroups and homomorphisms, isomorphism theorems of Noether, cyclic groups, cosets and quotient groups, theorems of Lagrange and Cauchy, normal subgroups, group action on a set, symmetric and dihedral groups, direct products. Sylow theorems, nilpotent and solvable groups,

Jordan-Holder theorem.

Rings, ideals and homomorphisms, polynomial rings and formal power series, UFDs and Euclidean rings, PIDs, Gauss' theorem on UFDs, Eisenstein's criterion for irreducibility.

Modules, homomorphisms and exact sequences, finitely generated modules over a PID, fundamental theorem of finitely generated abelian groups, Rational canonical form and Jordan canonical form. Projective, injective and free modules (if time permits).

TEXTBOOKS/REFERENCES

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

MAT 313 Linear Algebra [3003]

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

LU decomposition, cyclic decomposition, Matrix norms, positive definite matrices, Cholesky decomposition, condition numbers; orthogonal matrices, Householder transformation, Givens rotations, QR factorization, stability of QR factorization, singular value decomposition, sensitivity analysis of singular values and singular vectors, least square problems,

Sylvester's law of inertia, Sylvester's criterion for positive definite matrices, Tensor products, Bilinear forms.

TEXTBOOKS/REFERENCES

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

MAT 314 Numerical Analysis [3003]

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

Solutions of Linear Algebraic Equations: Direct Methods, Gauss Elimination, Pivoting, Matrix factorizations. Iterative Methods: Matrix Norms, Jacobi and Gauss-Siedel Methods, Relaxation Methods. Computation of eigenvalues and eigenvectors: Power method, Householder's method, QR algorithm. Numerical solutions of nonlinear algebraic equations: Bisection, Secant and Newton's method, Zeroes of polynomials, Horner and Muller methods, Equations in higher dimensions.
Ordinary Differential Equations, Initial Value Problems: Euler method, Higher order methods of Runge-Kutta type. Multi-step method, Adams-Bashforth, Adams-Moulton methods, System of ODEs. Boundary Value Problems: Shooting methods, Finite differences.

TEXTBOOKS/REFERENCES

1. K. E. Atkinson, *An Introduction to Numerical Analysis*, 2nd Edn., John Wiley, 1989.
2. E. K. Blum, *Numerical Analysis and Computation, Theory and Practice*, Addison Wesley Publishing Co., 1972.
3. R.L. Burden and J. D. Faires, *Numerical Analysis*, 7th Edn., Brookes/Cole, 2011.

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

MAT 315 Number Theory and Cryptography [3003]

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

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

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

TEXTBOOKS/REFERENCES

1. I. Niven, H. S. Zuckerman and H. L. Montgomery, *An Introduction to the Theory of Numbers*, 5th Edition, Wiley, 1991.
2. Neal Koblitz, *A Course in Number Theory and Cryptography*, 2nd Edition, Springer, 1994.

3. G. H. Hardy and E. M. Wright, *An Introduction to the Theory of Numbers*, 6th Edition, Oxford University Press, 2008.
4. Kenneth Ireland and Michael Rosen, *A Classical Introduction to Modern Number Theory*, 2nd Edition, Springer, 1990.
5. James K. Strayer, *Elementary Number Theory*, Waveland Press, 2001.

MAT 321 Complex Analysis [3003]

PREREQUISITE

1. MAT 311 Real Analysis

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

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

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

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

TEXTBOOKS/REFERENCES

1. L. V. Ahlfors, *Complex Analysis*, Mcgraw-Hill, 1980.
2. J. Bak and D. J. Newman, *Complex Analysis*, 3rd Edition, UTM, Springer, 2010.
3. J. W. Churchill and R. V. Brown, *Complex Analysis*, Mcgraw-Hill, 2009.
4. T. W. Gamelin, *Complex Analysis*, Springer-Verlag, 2001.
5. R. Greene and S. G. Krantz, *Function Theory of One Complex Variable*, 3rd Edition, GSM, Vol. 40, AMS, 2006.
6. E. M. Stein and R. Shakarchi, *Complex Analysis*, Princeton University Press, 2003.

MAT 322 Measure Theory and Integration [3003]

PREREQUISITE

1. MAT 311 Real Analysis

Outer measure, σ-algebra of measurable sets and its properties, Lebesgue measure and its properties, a non-measurable set, measurable functions.

Lebesgue integral of Simple functions, Lebesgue integral of a bounded function, bounded convergence theorem, Lebesgue integral of nonnegative measurable functions, Fatou's Lemma, monotone convergence theorem, the general Lebesgue integral, Lebesgue dominated convergence theorem.

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

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

TEXTBOOKS/REFERENCES

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

MAT 323 Galois Theory and Commutative Algebra [3003]

PREREQUISITE

1. MAT 312 Abstract Algebra

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

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

TEXTBOOKS/REFERENCES

1. M. Artin, *Algebra*, Phi Learning Pvt. Ltd., New Delhi, 2011.
2. M. F. Atiyah and I. G. McDonald, *Introduction to Commutative Algebra*, Westview Press, 1994.
3. B. Singh, *Basic Commutative Algebra*,World Scientific, 2011.
4. D. S. Dummit and R. M. Foote, *Abstract Algebra*, 3rd Edition, Wiley India, 2011.
5. S. Lang, *Algebra*, 4th ed., Springer 2005.
6. Thomas Hungerford, *Algebra*, Graduate Texts in Mathematics, Springer, 2005.

MAT 324 Theory of Ordinary Differential Equations [3003]

PREREQUISITE

1. MAT 311 Real Analysis

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

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

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

Stability theory: stability of nonlinear systems, two-dimensional autonomous systems, limit cycles and periodic solutions, Poincaré-Bendixson theory in 2-dimensions, Lyapunov's direct method for autonomous systems.

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

TEXTBOOKS/REFERENCES

1. Philip Hartman, *Ordinary Differential Equations*, 2nd Edn., SIAM, 2002.
2. E.A. Coddington and N. Levinson, *Theory of Ordinary Differential Equations*, McGraw-Hill, 1984.
3. Lawrence Perko, *Differential Equations and Dynamical Systems*, 3rd Edn., Springer, 2006.
4. Ravi P. Agarwal and Donal O'Regan, *An Introduction to Ordinary Differential Equations*, Springer, 2008.
5. G.F. Simmons, *Differential Equations with Applications and Historical Notes*, 2nd Edn., McGraw-Hill, 1991.
6. Hirsch and Smale, *Differential Equations, Dynamical Systems and Linear Algebra*, Academic Press, 1974.
7. Ivar Stakgold, *Green's Functions and Boundary Value Problems*, Wiley, New York, 1979.
8. G. Birkhoff and G-C Rota, *Ordinary Differential Equations*, 4th Edn., Wiley, 2004.

MAT 325 General Topology [3003]

PREREQUISITE

1. MAT 311 Real Analysis

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

Connectedness and Compactness: Connected spaces, connected sets in the real line, Components and path components, Local Connectedness, Compact spaces, Limit point compactness, Local compactness. Tychonoff's theorem for finite products.

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

The Tychonoff theorem, Completely regular spaces, one-point compactification.

Homotopy, Fundamental Groups, examples and computations.

TEXTBOOKS/REFERENCES

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

MAT 411 Functional Analysis [3003]

PREREQUISITES

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

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

1. R. Bhatia, *Notes on Functional Analysis*, Texts and Readings in Mathematics, 2009.
2. S. Kesavan, *Functional Analysis*, Hindustan Book Agency, 2014.
3. B. V. Limaye, *Functional Analysis*, New Age International, 2014.
4. V. S. Sundar, *Functional Analysis: Spectral Theory*, Birkhauser,1998.
5. J. B. Conway, *A course in Functional Analysis*, Springer, 1997.
6. Martin Schechter, *Principles of Functional Analysis*, AMS (Indian Edition, Uni. Press), 2009.
7. Peter D. Lax, *Functional Analysis*, Wiley-InterScience, 2002.
8. M. Reed and B. Simon, *Functional Analysis (Methods of Modern Mathematical Physics - Volume 1)*, Academic Press, 1981.
9. Y. Eidelman, V. Milman and A. Tsolomitis, *Functional Analysis: An Introduction*, GSM, Vol. 66, AMS, 2004.
10. B. Bollabas, *LinearAnalysis*, CambridgeUniversityPress(IndianEdition), 1999.
11. E. Kreyeszig, *Introduction to Functional Analysis with Applications*, Wiley, 1989.

MAT 412 Analysis on Manifolds [3003]

PREREQUISITES

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

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

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

Submanifolds in $\mathbb{R}^n$, tangent spaces.

Differential forms: Multilinear algebra, tensors, tensor products, alternating tensors, wedge product, tangent vectors, differential forms, orientation, Stoke's theorem, derivations of the classical formulations.

TEXTBOOKS/REFERENCES

1. J. R. Munkres, *Analysis on Manifolds*, Westview Press, 1997.
2. W. H. Flemming, *Functions of severable Variables*, Springer, 1987.
3. Michael Spivak, *Calculus on Manifolds*, Westview Press, 1971.
4. C. C. Pugh, *Real Mathematical Analysis*, Springer 2010.
5. S. Shirali and H. L.Vasudeva, *Multivariable Analysis*, Springer 2010.

MAT 413 Partial Differential Equations [3003]

PREREQUISITE

1. MAT 324 Theory of Ordinary Differential Equations

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

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

TEXTBOOKS/REFERENCES

1. Lawrence C. Evans, *Partial Differential Equations*, 2nd Edition, American Mathematical Society, 2010.
2. R. McOwen, *Partial Differential Equations: Methods and Applications*, 2nd Edition, Pearson, 2002.
3. Gerald B. Folland, *Introduction to Partial Differential Equations*, 2nd Edition, Princeton University Press, 1995.
4. Fritz John, *Partial Differential Equations*, 4th Edition, Springer, 1981.

5. Michael E. Taylor, *Partial Differential Equations I*, 2nd Edition, Springer, 2010.
6. S. Kesavan, *Topics in Functional Analysis and Applications*, Wiley, 1989.

MAT 421 Probability Theory and Stochastic Process[3003]

PREREQUISITE

1. MAT 322 Measure Theory and Integration

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

Random variables: distributions and expectations.

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

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

The central limit theorems: tight families of probability distributions, Prokhorov's theorem, Skorohod's theorem, compact support functions, the central limit theorem.

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

Basics of continuous time stochastic process, Poisson process and Brownian motion.

TEXTBOOKS/REFERENCES

1. K. B. Athreya and S. N. Lahiri, *Measure Theory and Probability Theory*, Hindustan Book Agency, 2006.
2. R. M. Dudley, *Real Analysis and Probability*, Cambridge University Press, 2002.
3. S. R. S. Varadhan, *Probability Theory*, Courant Institute of Mathematical Sciences, 2001.

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

MAT 422 Differential Geometry [3003]

PREREQUISITE

1. MAT 412 Analysis on Manifolds

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

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

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

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

TEXTBOOKS/REFERENCES

1. M. Spivak, *A Comprehensive Introduction to Differential Geometry*, vol. 1, Publish or perish, 1970.

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

Partial List of Electives

1. Algebraic Geometry
2. Algebraic Number Theory
3. Algebraic Topology
4. Rings, Modules and Algebras
5. Lie Groups and Lie Algebras
6. Representation Theory
7. Category Theory
8. Nonnegative Matrices and Applications
9. Operator Algebras
10. C^* Algebras
11. Graph Theory
12. Diophantine Approximations
13. Harmonic Analysis
14. Topics in Analysis
15. Topics in Applied Mathematics
16. Advanced Partial Differential Equations
17. Stochastic Analysis
18. Control Theory
19. Mathematical Finance
20. Financial Engineering
21. Mathematical Fluid Dynamics
22. Calculus of Variations
23. Operations Research
24. Discrete Mathematics
25. Programming and Data Structures
26. Finite Element Methods
27. Operator Theory
28. Ergodic Theory
29. Category Theory and Applications
30. Complex Geometry
31. Topics in Group Theory and Number Theory
32. Geometry of Schemes
33. Class Field Theory
34. Introduction to Nonnegative Matrices
35. Elliptic Curves and Modular Forms
36. Topics in Matrix Analysis
37. An Introduction to Stochastic Calculus and its Applications
38. Fourier Analysis
39. Matrix Analysis
40. Topics in Number Theory
41. Complex Dynamics
42. Mathematical Biology
43. Infinite Dimensional Stochastic Analysis
44. Wavelets and Frames
45. Geometric Measure Theory
46. Introduction to Data Science and Machine Learning
47. Introduction to Data Science
48. Machine Learning
49. Several Complex Variables

Physics Syllabus

THEORY COURSES

PHY 111 Mechanics [3103]

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

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

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

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

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

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

TEXTBOOKS

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

REFERENCES

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

PHY 121 Electromagnetism [3103]

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

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

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

TEXTBOOKS/REFERENCES

1. D. J. Griffths, *Introduction to Electrodynamics*, Prentice-Hall India, 2007.
2. E. M. Purcell, *Berkeley Physics course: Vol 2. Electricity and Magnetism*, McGraw Hill.

3. Serway and Jewett, *Physics for Scientists and Engineers*, Brooks/Cole Publishers, 2004.

PHY 211 Optics [3103]

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

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

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

Interference [7]:
The superposition principle, phasors and the addition of waves, Condition for interference, Coherence, Two beam interference by division of wavefront; Fresnel' Biprism, Interference by division of amplitude; interference by a plane parallel film, Newton's rings, Michelson interferometer, Multiple beam interferometry; Fabry-Perot interferometer.

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

TEXTBOOKS

1. Eugune Hecht and A. R. Ganesan, *Optics*, Addison Wesley Longman, 2002.
2. Francis A. Jenkins and Harvey E. White, *Fundamentals of Optics*, McGraw-Hill Higher Education, 4th Edition.

REFERENCES

1. Ajoy Ghatak, *Optics*, Tata Mgraw-Hill, 2009.
2. Frank S. Crawford, *Waves: Berkeley Physics Course Vol. 3*, Tata Mgraw Hill, 2008.

PHY 221 Thermal and Statistical Physics [3103]

Macroscopic description of the state, Extensive and intensive variables, Thermodynamic variables (pressure, temperature, etc), Thermal equilibrium, Equation of State, Zeroth Law of Thermodynamics. [3]

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

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

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

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

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

TEXTBOOKS

1. M. W. Zemanski and R. H. Dittman, *Heat and Thermodynamics*, McGraw-Hill, 1997.

2. F. Reif, *Statistical Physics: Berkeley Physics Course Vol. 5*, Tata Mcgraw-hill, 2011.

REFERENCES

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

PHY 311 Mathematical Methods in Physics [3003]

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

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

Special functions and Applications [2].

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

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

TEXTBOOKS/REFERENCES

1. G. B. Arfken and H. J. Weber, *Mathematical methods for physicists*, Academic press.
2. Murray Spiegel, Seymour Lipschutz, John Schiller and Dennis Spellman, *Schaum's Outline of Complex Variables*, 2ed (Schaum's Outline Series).

3. Tulsi Dass and Satish K Sharma, *Mathematical methods in classical and quantum physics*, Universities Press.
4. Dennery and Andre Krzywicki, *Mathematics for Physicists*, Dover.

PHY 312 Classical Mechanics [3003]

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

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

TEXTBOOKS/REFERENCES

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

PHY 313 Electronics I [3003]

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

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

AC and DC analysis of transistor circuits amplifiers and differential am-

plifiers.

Operating principles of FET, MOSFET and Operational amplifiers.

TEXTBOOKS/REFERENCES

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

PHY 314 Quantum Mechanics I [3003]

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

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

The Schrödinger equation in three dimensions: The Schrödinger equation in spherical coordinates, Separation of variables, The radial equation and energy quantization, the angular equation, spherical harmonics and introduction to quantized angular momentum. Spin, The Hydrogen atom;

Charged Particle in a Magnetic Field: Oscillator algebra; Energy spectrum and Eigenstates; Landau levels, Wave functions.

TEXTBOOKS/REFERENCES

1. D. J. Griffiths, *Introduction to quantum mechanics*, Benjamin-Cummins, 2004.
2. J. J. Sakurai, *Modern quantum mechanics*, Addison-Wesley, 1994.
3. R. Shankar, *Principles of quantum mechanics*, Plenum Publishers, 1994.

PHY 321 Statistical Mechanics [3003]

Review of thermodynamics and Probability theory: The Laws of Thermodynamics. Interactions The Conditions for Equilibrium, Thermal Interaction Temperature, Volume change Pressure, Particle interchange chemical potential. Random variable, Distribution function, Central limit theorem; Statistical Picture of Mechanics: Statistical description of a classical particle, Dynamics in Phase space, Ergodicity, Stationary states and Liouville theorem, Microcanonical and Canonical states.

Methadology of Statistical Mechanics: Definition of counting and partition function Density of states, Classical Partition function, Examples Two level system, Harmonic oscillator, Particle in a 1D and 3D box. Equipartition theorem, Virial theorem; Thermodynamic Averages: The Partition Function, Generalised Expression for Entropy Gibbs entropy, Free Energy and Thermodynamic Variables, The Grand Partition Function , Grand Potential and Thermodynamic variables, Examples of non-interacting systems Einstein and Debye model, Ideal Paramagnet (negative temperature).

Quantum Distributions: Bosons and Fermions, Grand Potential for Identical Particles, The Fermi and Bose Distribution, The Classical Limit The Maxwell Distribution, Examples: Black-body radiation, Bose Einsten Condensation and Fermi gas at low temperatures. Weakly interacting Systems: Cluster Expansion, Van der Waal's gases; Phase transitions - Phenomenology: Phase diagrams, Symmetry, Order of phase transitions and Order parameter, Conserved and non-conserved order parameters, Critical exponents, Scaling theory and scaling of free energy.

Strongly interacting systems – Phase transitions: Introduction to the Ising model. Magnetic case, lattice gas and phase separation in alloys and Bragg-Williams approximation. Transfer matrix method in 1D. Landau

theory, Symmetry breaking, Distinction between second order and first order transitions, Discussion of ferroelectrics. Broken symmetry, Goldstone bosons, fluctuations, scattering, Ornstein Zernike, soft modes.

TEXTBOOKS/REFERENCES

1. F. Reif, *Statistical Physics: Berkeley Physics Course Vol. 5*, Tata Mcgraw-hill, 2011.
2. F. Mandl, *Statistical Physics* (2^{nd} Ed.), John Wiley & Sons, 1991.
3. H. B. Callen, *Thermodynamics and an Introduction To Thermostatistics*, Wiley, 2006.
4. R. K. Pathria, *Statistical Mechanics* (2^{nd} Ed.), Elsevier, 2002.

PHY 322 Condensed Matter Physics I [3003]

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

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

TEXTBOOKS/REFERENCES

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

PHY 323 Electronics II [3003]

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

Advanced Electronic Materials: Optoelectronic properties and applications.

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

Digital analog and Analog Digital Converters.

Flip-flops, Counters and Shift registers.

TEXTBOOKS/REFERENCES

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

PHY 324 Electrodynamics and Special Theory of Relativity [3003]

PREREQUISITE

1. Classical Mechanics [PHY 312]

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

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

Charges in electromagnetic fields [6]:
Elementary particles in special theory of relativity, Four potential of a

field, Gauge invariance, Electromagnetic field tensor, Lorentz transformation of the electromagnetic field, Invariants of the field.

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

Constant electromagnetic fields [3]:
Coulomb's law, Electrostatic energy of charges, The field of a uniformly moving charge, Motion in the coulomb field, The dipole and multipole moments, System of charges in an electric field, Magnetic field and moments. Larmor's theorem.

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

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

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

TEXTBOOKS

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

REFERENCES

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

PHY 411 Experimental Methods [3003]

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

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

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

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

Sample deposition Techniques: Thermal, electron beam, Knudsen Cell, RF/DC sputtering, applications and limitations. Thickness measurement, profilometer etc. Selected Characterisation techniques:-Principle of pulse NMR, measurements of NMR spectra, spin-lattice relaxation time (T1) and spin-spin relaxation time (T2); Basic principles of Electron Spin Res-

onance (ESR) and its application; Magnetic measurement, principle of Vibrating Sample Magnetometer (VSM) and SQUID magnetometer; Measurement of heat capacities.

TEXTBOOKS/REFERENCES

1. Charles P. Slichter, *Principles of Magnetic Resonance*, Springer, 1989.
2. R. A. Dunlap, *Experimental Physics - Modern Methods*, Oxford University Press, 1988.
3. JH. Moore, C C. Davis, M A Coplan, S C. Greer, *Building Scientific Apparatus* , Cambridge University Press, (4th Ed) 2009.
4. Low Level Measurements Handbook (6/7th Ed) Keithley Instruments Publication (available online).
5. G. L. Weissler, R W Carlson, *Methods of Experimental Physics Volume 14 : Vacuum Physics and Technology* , Academic Press, 1990.
6. G K. White, P. Meeson, *Experimental Techniques in Low Temperature Physics* (3rd/4th Ed) , Oxford University Press, 1979.
7. C. J. Chen, *Introduction to Scanning Tunnelling Microscopy* (2nd Ed), Oxford University Press, 2008.
8. Vacuum Technology Know How, Pfeiffer Vacuum, 2011 (available online)

PHY 412 Condensed Matter Physics II [3003]

PREREQUISITE

1. PHY 322: Condensed Matter Physics I

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

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

Superconductivity: Experimental survey, Thermodynamics of superconductors, Meissner effect, Londons equation, BCS theory, Ginzburg-Landau theory, flux quantization, coherence length, Type-I and Type-II superconductors, Superconducting tunneling, DC and AC Josephson effects,

SQUIDs, High-T superconductivity: structure and transport properties.

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

TEXTBOOKS/REFERENCES

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

PHY 413 Quantum Mechanics II [3003]

PREREQUISITES

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

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

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

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

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

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

TEXTBOOKS/REFERENCES

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

PHY 421 High Energy Physics [3003]

PREREQUISITE

1. PHY 413: Quantum Mechanics II

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

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

Invariance Principles and Conservation Laws: Origin of conservation laws, properties of space-time, Conservation of p, E and L, Global phase or gauge transformations, Properties of the gauge groups $U(1)$, $SU(2)$

and $SU(3)$ (Additive and) multiplicative conservation laws, charge conjugation (C), parity (P) and time-reversal (T) symmetries, CPT theorem.

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

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

TEXTBOOKS/REFERENCES

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

PHY 422 Atomic and Molecular Physics [3003]

PREREQUISITE

1. PHY 413: Quantum Mechanics II

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

Many electron atoms: The central field approximation, Hartree-Forck

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

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

TEXTBOOKS/REFERENCES

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

PHY 423 Computational Techniques and Programming Languages [3003]

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

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

Methods of Integration: Methods: Mid-point rule, Trapezoidal Rule, simpson's rule, errors; *Physical Problems:* First-order, second-order corrections in Perturbation theory, Magnetic field produced by the current; Partial Differential Equations: Methods: Finite difference method, Re-

laxation Method, Crank-Nicholson scheme, Shooting Method, Spectral Methods;*Physical Problems:* Solving Diffusion Equation, Wave Equation, Poisson equation.

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

TEXTBOOKS/REFERENCES

1. Paul Devries and Javier Hasbun, *A First Course on Computational Physics*.
2. Nicholas Giordano and Hisao Nakanishi *Computational Physics* (2^{nd} Ed.), Prentice-Hall.

Partial List of Electives in Physics

Sl. No.	Experimental/Applied Courses	Sl. No.	Theory Courses
1.	Semiconductor Physics and Technology (PHYxxxx) Prerequisites: Electronics-I	1.	Quantum Field Theory (PHYxxx) Prerequisites: QM-II, ED and STR
2.	Quantum Transport (PHYxxxx) Prerequisites: CMP-I and QM-I	2.	Quantum Information Theory (PHYxxxx) Prerequisites: QM-I
3.	Principles of Digital Imaging (PHYxxxx) Prerequisites: Numerical Methods (familiarity with MATLAB)	3.	Non-linear Dynamics (PHYxxxx) Prerequisites: Mathematical Methods in Physics
4.	Nanoscale Physics (PHYxxxx) Prerequisites: CMP-I and QM-I	4.	Numerical Simulation Techniques in Physics (PHYxxxx)
5.	Non-linear Optics and Photonics Prerequisites: Mathematical Methods in Physics	5.	General Relativity and Cosmology (PHYxxxx) Prerequisites: Classical Mechanics, ED and STR
6.	Lasers and Fiber Optics (PHYxxxx) Prerequisites: QM-I and Mathematical Methods in Physics	6.	Astrophysics (PHYxxxx) Prerequisites: ED and STR, Classical Mechanics, Statistical Mechanics
7.	Organic Semiconductors: Fundamentals and Applications (PHYxxxx)	7.	Quantum Many-body Theory (PHYxxxx) Prerequisites: QM-II
8.	Sensor Technology (PHYxxxx) Prerequisites: CMP-I and Electronics-I	8.	Fluid Dynamics (PHYxxxx) Prerequisites: Classical Mechanics, ED and STR, Statistical Mechanics
9.	Low Temperature Physics (PHYxxxx)	9.	Advanced Statistical Physics (PHYxxxx) Prerequisites: Statistical Mechanics
10.	Probes in Condensed Matter Physics (PHYxxxx)		

LABORATORY COURSES

PHY 112 Experiments in Mechanics [0031]

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

PHY 122 Experiments in electrodynamics [0031]

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

PHY 212 Experiments in Optics [0031]

1. Convex lens
2. Concave mirror
3. Spectrometer-refractive index of prism
4. Spectrometer-Grating
5. Newton's rings
6. Diffraction at slits-single and double
7. Liquid lens

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

PHY 222 Experiments on Heat and Thermodynamics [0031]

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

PHY 315 Advanced Physics Experiments I [0093]

1. Viscosity of a liquid - Oscillating disc method
2. Young's modulus: Cornu's method
3. Spectrometer- $i - i'$ curve
4. Spectrometer- Hartmann's constant
5. Young's modulus- Optic lever method
6. Surface tension- Capillary method
7. Beam profile of laser
8. Diffraction by ultrasonic waves- velocity of sound in liquid
9. e/m - Thomson's method
10. Fabry-Perot interferometer
11. Michelson's interferometer
12. LCR circuit (series and parallel)- Frequency response and the value of unknown L
13. Transistor characteristics and transistor as an amplifier
14. Phase shift oscillators

PHY 325 Advanced Physics Experiments II [0093]

1. Velocity of light- Foucoult's method

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

PHY 414 Advanced Physics Experiments III [0093]

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

Interdisciplinary Courses

IDC 111 Mathematical Tools I [2023]

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

Mathematica Exercises: [4 weeks]
Introduction to MATHEMATICA. Importing/exporting formatted datasets. Plotting of functions and data in 2D, 3D; Plotting parametrically defined functions. Basic mathematical operations; symbolic differentiation of single and multi variable functions. Simple data fitting (e.g. polynomial, exponential functions etc), error estimation. Examples for Taylor series expansion, demonstration of convergence. Programming in MATHEMATICA, debugging and execution.

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

Mathematica Exercises: [4 weeks]
Plotting vectors in 3D; algebraic operations, span and linear independence. Visualizing the plane determined by two vectors; determining the unit normal from vector product. Obtaining equation of the plane and parametric representation of the same. Plotting a system of simple contours and surfaces as a visual representation of scalar fields. Determining the gradient of a scalar field and graphical representation of the gradient as vectors. Visualization of various types of vector fields (divergent, rota-

tional etc.) in 2D and 3D. Determination of divergence and curl of vector fields and their graphical representation. Real life scalar (temperature) and vector fields (static and rotating garden sprinkler, liquid vortex) and practical applications of the gradient, divergence and curl.

Fourier Series:
Fourier expansion of a periodic functions.

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

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

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

TEXTBOOKS

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

IDC 121 Mathematical Tools II [2023]

Matrices:
Revision of Matrices, Matrix operations, Hermitian adjoint and inverse of a matrix; Hermitian, orthogonal, and unitary matrices; Eigenvalue and eigenvector (for both degenerate and non-degenerate cases); Similarity transformation; diagonalisation of real symmetric matrices.

Matlab/Octave/Python Hands-ON Exercises: [4 weeks]
Introduction to MATLAB/Octave/Python. Data handling. Basic Plotting 2D and 3D. 2D Matrix operations and manipulation; Addition, subtraction, inverse, transpose, multiplication, element by element operations. Check whether given matrix is symmetric, hermitian, unitary, orthog-

onal, antisymmetric, singular. Diagonalisation and Eigenvalue problem. Regression Analysis.

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

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

TEXTBOOKS

1. E. Kreyszig, *Advanced Engineering Mathematics*, 8th Edition Wiley India Pvt Ltd, 2006.
2. Richard Bronson, Gabriel Costa, *Schaum's Outlines Differential Equations*, 3rd Edition Mcgraw-hill 2009.
3. C. Edwards and D. Penny, *Elementary Differential Equations with Boundary Value Problems*, 5th Edition Prentice Hall 2007.

IDC 211 Physical Principles in Biology

A. Physical biochemistry of the cell: Chemical forces translation and rotation, diffusion, directed movements, bio-molecules as machines, work, power and energy, thermal, chemical and mechanical switching of bio-molecules, Responses to light and environmental cues
B. Physical principles of molecular structure: organization of biomolecules, molecular census in size and time, macromolecular assemblies, sizing up HIV, channels, transporters and motors
C. Molecular recognition: principles of specificity in biological recognition, hormone-receptor interaction, antigen-antibody interaction, transient interactions, importance of transient interaction in biology.
D. Linearity and non-linearity in biological systems : Definitions and example of linear and non-linear systems. Representing linear and non-linear functions and applications (3-4 lectures)

E. Stochasticity in Biological systems (3-4 lectures)

REFERENCES:

1. John Kuriyan, *The Molecules of Life: Physical and Chemical Principles*, Garland Science (Taylor & Francis group); 1 edition, 2013.
2. Rob Phillips et al., *Physical Biology of the Cell*, Garland Science. 2nd Edition. 2012.
3. Peter Atkins and Julio de Paula. *Physical Chemistry for the Life Sciences*, Oxford University Press. 2nd Edition. 2011.

IDC 221 Principles and Applications of Spectroscopy [3103]

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

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

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

Raman Spectroscopy: Light scattering and Raman effect, classical model for scattering, Stokes and anti-Stokes lines, polarizability.

Spin Resonance Spectroscopies: nuclear spin and electron spins, effect of applied external fields, Nuclear Magnetic Resonance (NMR) spectroscopy, Electron Spin Resonance (ESR) spectroscopy, basic principles and examples.

Mössbauer Spectroscopy: Principles and applications.

TEXTBOOKS/REFERENCES

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

Courses for Data Science

The following courses will be offered as Data Science minor:

1. Introduction to Computing (3 Credits)
2. Introduction to Data Science (3 Credits)
3. Machine Learning (3 Credits)
4. Minor Project (6 Credits)

Open Applied Science Elective courses

School of Biology will offer

1. Biological Data Analysis (3 Credits)
2. Stem Cells and Regenerative Medicine (3 Credits)

School of Chemistry will offer

1. Computational Molecular Modeling (3 Credits)
2. Modeling: From Atoms to Materials and Biology (3 Credits)

School of Mathematics will offer

1. Introduction to Computing (3 Credits)
2. Cryptography and Data Security (3 Credits)
3. Design and Analysis of Algorithms (3 Credits)

School of Physics will offer

1. Digital Image Processing (3 Credits)
2. Materials and Device Characterization Techniques (3 Credits)
3. Materials Growth and Processing Techniques (3 Credits)

Humanities Syllabus

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

Introduction to Psychology

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

Theories of Personality

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

Environment, Development and Society

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

Introduction to Sociology

The course will introduce students to the study of sociology and some basic underpinnings of sociological theory and methodology. The emergence of sociology as a scientific discipline is examined in the context of the development of Industrial society in Western Europe. The course will examine the writings of key classical social thinkers such as Marx, Durkheim and Weber as well as more contemporary theorists such as Michel Foucault, with a view to understanding various sociological approaches to modern industrial society Integrity, anti-corruption and ethics: Cross cutting nature of Corruption and its impact on Socio-economic development; Corruption Prevention and control mechanism; Challenges of corruption prevention and integrity; Ethical models in public and private sectors.

Science, Technology and Society

The course will begin with social theories on the production of technology and scientific knowledge systems, stratification within the community of technologists and scientists, discrimination (race, class, gender, caste) and the role of power in shaping the production of technology and scientific knowledge. Scientific controversies, both historical and emerging, and the organization of innovation and its geographies will be discussed. Case studies exploring ethical questions arising from new technologies

such as information technology, nanotechnologies, biotechnologies, etc. will be used. Discussions on public understanding of science and role of the public and of experts in influencing policies related to science and technology will conclude the course.

Introduction to Logic

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

Introduction to Philosophy

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

Indian School of Philosophy: Introduction and general characteristics of Indian Philosophy; Classification; Swami Vivekanda and Vedanta Philosophy; The significance of Upanishad and Vedas.

Philosophy of Mind

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

ontologically, from the rest of nature; Yoga and Meditation: The Philosophical and Psychological characteristics.

Philosophy of Science

Science is regarded as the most significant cognitive enterprise of the modern society. In view of this, the course addresses the question what sets science apart from other epistemic activities. Further It concentrates on debates on the nature of scientific methods, logical reconstruction of scientific explanation, the relation between theories and laws on the one hand, and empirical evidence on the other, the nature of the justification and the notion of truth involved in scientific knowledge, and the societal influence on scientific practice.

Communication Skills (Advanced Level)

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

Introduction to Economics

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

Planning and Economic Development (Advanced Level)

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

International Economics

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

Industrial Economics

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

Applied Game Theory

This module introduces students in economics and other social sciences to game theory, a theory of interactive decision making. This module pro-

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