Course Structure and Syllabus

Master of Science (M. Sc.)/ Integrated PhD

SCHOOL OF APPLIED AND INTERDISCIPLINARY SCIENCES

Indian Association for the Cultivation of Science

2021

M. Sc. in CHEMICAL Sciences (POLYMER SCIENCE AND SOFT MATTER)

SEMESTER-1 (4 Core Theory + 1 Core Lab + 1 non CGPA Core Theory)				
Course Name	**Course Title**	**L-T-P**	**Credit**	**Page No.**
AIS-4101 / CHS4103	Organic Chemistry-I	3-1-0	4	5
AIS-4102 /BIS 4104	Biophys. & Biochem. Methods	3-1-0	4	-
AIS-4103/CHS 4101	Quantum Mechanics	3-1-0	4	-
AIS-4104/CHS 4102	Inorganic Chemistry: Structure and Reactivity	3-1-0	4	6
AIS 4105C	Laboratory	0-0-12	6	-
AEC 4100	Communicative English	2-0-0	2	-
SEMESTER-2 (4 Core Theory + 1 Core Lab + 1 non CGPA Core Theory)				
AIS 4201/CHS 4203	Organic Chemistry-I	3-1-0	4	7
AIS-4202	Macromolecules-I	3-1-0	4	-
AIS-4203/ CHS 4201	Thermodynamics and Statistical Mechanics	3-1-0	4	8
AIS-4204/ CHS 4204	Group Theory and Molecular Spectroscopy	3-1-0	4	9
AIS-4205C	Laboratory	0-0-12	6	-
SEC 4200	Seminar and Colloquium	2-0-0	2	9
Summer Internship for 2 months				
SEMESTER-3 (1 Core Theory + 2 DSE Theory+ 1GE Theory+1 Core Project)				
AIS-5101 (Core)	Macromolecules-II	3-1-0	4	10
GE-1	Depends on the choice of the student	3-1-0	4	-
DSE-1	Any two from the following list	3-1-0	4 + 4	-
DSE-2	AIS-5102: Drug Design and Delivery	3-1-0		-
	AIS-5104: Fabrication and Characterization of Soft Materials			11
	AIS-5117: Polymer Processing			-
	AIS-5121: Organic Optoelectronics: Materials, Mechanisms and Devices			12
				-
AIS-5105	Project with Seminar	0-0-16	8	-
AEC 5100	Scientific Writing and Ethics	2-0-0	2	-
SEMESTER-4 (1 Core Theory + 2 DSE Theory+ 1GE Theory+1 Core Project)				
AIS-5201 (core)	Supramolecular and Macromolecular Biomaterial	3-1-0	4	13
GE-2	Depends on the choice of the student	3-1-0	4	-
DSE-3	Any two from the following list		4 + 4	
	AIS-5214: Engineering and Speciality Polymers	3-1-0		13
DSE-4	AIS-5203: Liquid Crystals and Display	3-1-0		14
	AIS- 5215: Colloids and Surfaces			-
	AIS-5204: Advanced Energy Systems and Applications			-
	AIS-4206: Chemistry of Biological Systems			15
	AIS-5218: Molecular Machinery Basics			16
	AIS-5219: Advanced Simulation and Data Science			-
AIS-5206	Project with Seminar	0-0-16	8	17
SEC-5200	Seminar/ Colloquium	2-0-0	2	-

M.Sc. in BIOLOGICAL Sciences (MOLECULAR BIOSYSTEMS AND BIOMEDICINE)

Course Name	Course Title	L-T-P	Credit	Page No.
SEMESTER-1(4 Core Theory + 1 Core Lab + 1 non CGPA Core Theory)				
AIS-4102/ BIS 4104	Biophys. & Biochem. Methods	3-1-0	4	18
AIS-4106/ BIS 4101	Advanced Cell Biology	3-1-0	4	-
AIS-4107/ BIS 4103	Advanced Molecular Biology	3-1-0	4	-
AIS 4108	Chemistry for Biologists	3-1-0	4	19
AIS-4105B	Laboratory	0-0-12	6	-
AEC-4100	Communicative English	2-0-0	2	20
SEMESTER-2(4 Core Theory + 1 Core Lab + 1 non CGPA Core Theory)				
AIS-4202	Macromolecules-I	3-1-0	4	-
AIS-4206	Chemistry of Biological Systems	3-1-0	4	21
AIS-4208	Infection and Immunity	3-1-0	4	-
AIS-4209 / BIS 4202	Molecular Microbiology	3-1-0	4	-
AIS-4205B	Laboratory	0-0-12	6	22
SEC 4200	Seminar and Colloquium	2-0-0	2	-
Summer Internship for 2 months				
SEMESTER-3(1 Core Theory + 2 DSE Theory+ 1GE Theory+1 Core Project)				
AIS-5102 (core)	Drug Design and Delivery	3-1-0	4	22
GE-1	Depends on the choice of the student	3-1-0	4	-
DSE-1	Any two from the following list:	3-1-0	4 + 4	-
DSE-2	AIS-5108/ SBS C16: Computational Biology and Bioinformatics			23
	AIS-5109/ SBS GE-2/ DSE-6: Functional Materials in Biology			-
	AIS-5110/ SBS GE-1/DSE-5: Pharmacokinetics and Pharmacogenomics			-
	AIS-5119: Virology			-
	AIS-5120: Synthetic Biology			24 25
AIS-5105	Project with seminar	0-0-16	8	-
AEC-5100	Scientific Writing and Ethics	2-0-0	8	-
SEMESTER-4(1 Core Theory + 2 DSE Theory+ 1GE Theory+1 Core Project)				
AIS-5202/ BIS-C17(Core)	Disease Biology	3-1-0	4	25
GE-2	Depends on the choice of the student	3-1-0	4	-
DSE-1	AIS-5201: Supramolecular and Macromolecular Biomaterial		4 + 4	-
DSE-2		3-1-0		-
	AIS-5208: Biomaterials and Tissue Engineering			26
	AIS-5209/ BT 41022: Neurophysiology			-
	AIS-5210/MS5404: Nanobiotechnology			-
	AIS-5216: Gene Therapy			27
	AIS-5217: Epigenetics	3-1-0		-
AIS-5206	Project with seminar	0-0-16	8	-
SEC 5200	Seminar/ Colloquium	2-0-0	2	-

SEMESTER-1(4 Core Theory + 1 Core Lab + 1 non CGPA Core Theory)				
Course Name	**Course Title**	**L-T-P**	**Credit**	**Page No.**
AIS-4110/ PHS4101	Classical Mechanics-I	3-1-0	4	28
AIS-4111/PH4102	Quantum Mechanics-I	3-1-0	4	-
AIS-4112/ PHS4103	Mathematical Methods-I	3-1-0	4	-
AIS-4113 / PHS 4104	Electronics	3-1-0	4	-
AIS-4105P	Laboratory (2 Comp. + 4 as per mentioned)	0-0-12	6	29
AEC-4100	Communicative English	2-0-0	2	-
SEMESTER-2(4 Core Theory + 1 Core Lab + 1 non CGPA Core Theory)				
AIS-4210/ PHS4204	Statistical Mechanics	3-1-0	4	29
AIS-4211/ PHS4203	Electromagnetic Theory	3-1-0	4	30
AIS-4212	Soft Matter Physics	3-1-0	4	-
AIS-4213/ MS4202	Advanced Device Physics	3-1-0	4	-
AIS-4205P	Laboratory	0-0-12	6	-
SEC-4200	Seminar and Colloquium	2-0-0	2	31
Summer Internship for 2 months				
SEMESTER-3 (1 Core Theory + 2 DSE Theory+ 1GE Theory+1 Core Project)				
AIS-5103 (Core)	Energy Generation and Harvesting Technologies	3-1-0	4	31
GE-1	Depends on the student	3-1-0	4	32
DSE-1	AIS-5112/ PH505: Condensed Matter Physics	3-1-0	4 + 4	-
DSE-2	AIS-5114: Physics of Materials / Nanomaterials			-
	AIS-5116/ MS5302: Magnetic Properties of Solids			-
	AIS-5104: Fabrication and Characterization of Soft Materials			33
	AIS-5121: Organic Optoelectronics: Materials, Mechanisms and Devices			-
				-
				34
AIS-5105	Project with seminar	0-0-16	8	-
AEC-5100	Scientific Writing and Ethics	2-0-0	2	-
SEMESTER-4(1 Core Theory + 2 DSE Theory+ 1GE Theory+1 Core Project)				
AIS-5203 (core)	Liquid Crystals and Display	3-1-0	4	35
GE-1	Depends on student's choice	3-1-0	4	-
DSE-3	AIS-5207**:** Physics and Chemistry of Fluids	3-1-0	4 + 4	-
DSE-4	AIS-5204**:** Advanced Energy Systems and Applications			
	AIS-5211/ PH 524: Nanoscale Materials			36
	AIS-5218: Molecular Machinery Basics			37
	AIS 5219: Advanced Simulation and Data Science			39
	AIS-5220: Advanced Condensed Matter Physics			38
AIS-5206	Project with seminar	0-0-16	8	-
SEC-5200	Seminar/ Colloquium	2-0-0	2	

Course Content

M.Sc. in Chemistry (Semester-1)

AIS-4101: Organic Chemistry-1

Content:

Conformational analysis of acyclic and cyclic structures, conformational effect on reactivity; Baldwin's rule and Thorpe ingold effect, Stereoelectronic Effects (Cram's rule, Felkin-Anh Model, Cieplak Model), different aspects of chirality.
Frontier orbitals in organic reactions; orbital symmetry and pericyclic reactions; control of stereochemistry and secondary orbital interactions;
Reactive intermediates; carbenes and nitrenes; introduction of free radical chemistry; SET pathways.
Introduction to reaction mechanism; physical methods of determination of reaction mechanism; kinetic vs thermodynamic control, kinetic isotope effect, Curtin–Hammett principle.
Organic photochemistry; Principles and reactions - photolytic cleavage, photoreduction, photooxidation, photoaddition, photorearrangement.

AIS 4102: Biophys. and Biochem. Methods

Content:

Overview of modern biophysical and biochemical experimental techniques; Spectroscopy theory: Electromagnetic and quantum theory of radiation, wave particle duality, Light matter interaction, Transition dipole moment, Jablonsky diagram, Bear Lambert's Law. Spectroscopy - UV-visible, IR, fluorescence spectroscopy and circular dichroism (CD); Microscopy & Imaging - optical microscopy, confocal fluorescence microscopy, atomic force microscopy; Molecular interaction - fluorescence resonance energy transfer (FRET), surface plasmon resonance (SPR), isothermal titration calorimetry (ITC); Mass Spectrometry. Application in characterization of Bio molecules.

Analytical and preparative chromatographic separation techniques - general concepts, dynamics of zone migration, multi-component adsorption, chromatographic dispersion, linear and non-linear chromatography; liquid chromatographic techniques - size exclusion, ion exchange, affinity and reverse phase chromatography

AIS-4103 / CHS 4102**: Quantum Mechanics**

Content;

- Sequence of events/phenomena which establish that (i) both radiation and matter have wave-particle duality and (ii) physical variables can be discrete/quantized. Elementary classical mechanics, using linear harmonic oscillator (LHO) as an example. Trajectories in configuration space and phase space. Lagrange‟s and Hamilton‟s equations of motion. Poisson‟s bracket. Classical wave equation. Planewave solutions. De Broglie matter waves. Operators. Linear Operators. The eigenvalue problem; occurrence of quantization, bounded and unbounded systems, discrete and continuous eigenvalue spectra. Commutation relations, commuting and non-commuting operators, eigenfunctions.

- Probability distribution (weighting function) and expectation value. Operations of observation and their properties; parallelism with commuting/non-commuting eigenoperators. "Small" and "large" systems; origin of uncertainty and connection to commutation relations.

- Postulates of quantum mechanics and their interpretations. Schrödinger equation and various

interpretations of equation, energy spectrum, wave functions (Hilbert space), operators and Dirac notation (vectorial analogy). Hermitian operators. Acceptability conditions restricting energy values. Proof of Uncertainty Principle. Parity of eigenfunctions. Ehrenfest theorem. Heisenberg equation of motion.

- Applications to one-, two- and three-dimensional systems, degeneracy, Jahn-Teller effect. LHO (in terms of ladder/creation-annihilation operators), rigid rotor (including electron in a ring), hydrogen atom (ladder operators). One-dimensional periodic potential; Bloch theorem, band structure.

- Angular momentum in quantum mechanics in terms of ladder operators. Electron spin; Pauli spin matrices. Spin and magnetic field. Exchange; Slater determinant. Spin-orbit coupling. Spectral term symbols.

- Approximate methods: Time-independent and time-dependent perturbation theories; their applications. The variation principle for ground and excited states.

AIS-4104 / CHS 4103**: Inorganic Chemistry: Structure and Reactivity**

Content:

- Structure and Reactivity of Inorganic Molecules: Chemical forces, bonding models in inorganic chemistry; molecular orbital theory; acid-base chemistry; chemistry of aqueous and non-aqueous solvents; redox chemistry.

- Basic Principles of Coordination Chemistry: Coordination number and ligand polytopes; isomerism in coordination complexes; transition metal complexes involving redox-non-innocent ligands-formal and spectroscopic oxidation states; structure, bonding, spectral and magnetic properties; reaction mechanism.

- Bioinorganic Chemistry: Essential elements in biological systems; abundance, availability and bioavailability of the elements; role of metal ions in basic chemical reactions in the biological systems; metal ion transport across membrane; uptake, transport and storage of iron, biomineralization; dioxygen Carriers: Hb, Mb, Hc, Hr; electron transfer proteins (basic); hydrolytic enzymes; metals in medicine.

AIS 4105C: Laboratory

Content:

Synthesis

- Synthesis and purification of an organic compound by column chromatography and characterization by UV/ Vis, ^{1}H NMR, ^{13}C NMR and FT-IR spectroscopy
- Synthesis of a drug (Acylation of 6-aminopenicillanic acid) and studying its antibacterial properties

Self-assembly

- Preparation of a liposome from a commercially available lipid and it characterization by DLS and TEM
- Preparation of a surfactant micelle and determination of CMC by fluorescence probe
- Preparation of a hydrogel from well known gelator and characterization (Tg by DSC, Rheology)

Photophysical studies

- Preparation of nano-material based photonic crystals
- Estimation of fluorescence QY (relative) of a organic fluorophore by external standard
- Estimation of association constant of a donor-acceptor charge transfer complex by UV/ Vis spectroscopy

AEC 4100: Communicative English

M.Sc. in Chemistry (Semester-2)

AIS-4201: Organic Chemistry-II

Objectives:

1. To teach about different types of reagents for organic transformations.
2. Mechanism of the reactions and the reactivity of the reagents.
3. Selectivity of the reagents for functional group transformations.

Content:

- Reducing agents, Birch reductions, Oxidizing agents
- Protecting group chemistry
- Wittig olefination and Horner-Wadsworth-Emmons Olefination
- The Olefin Metathesis Reaction
- Pd-mediated carbon-carbon bond formation
- Directed ortho-metallation and Grignard reaction
- Selective name reactions (Bamford-Stevens reaction, Eschenmoser Fragmentation, Mitsunobu reaction, Macrocyclization, Stuadinger reaction or ligation, Baldwin's rule for ring closure, Michael reaction, Robinson's annelation, Curtius rearrangement, Iodolactonization or halolactonization, Fischer indole synthesis, Larock's heteroannulation, Dihydroxylation of olefins), Umpolung effect.
- Epoxidation and aziridination reactions
- Use of DCC, HOBt, HOAt, HBTU for peptide synthesis
- Combinatorial chemistry and diversity oriented synthesis (DOS).
- Useful reactions in bioconjugation chemistry

Outcome:

Students will develop the knowledge about the fundementals and applications of the reagents and reactions in organic synthesis. This will help them to appear for CSIR NET exam and other competitive exams and would be useful for working in organic synthesis area.

AIS-4202: Macromolecules-1

Objectives:

1) It is an introductory course to polymer chemistry. In this course, students will gain knowledge about the historic origin of synthetic polymers, different classifications of polymers, their properties, characterization and uses.
2) Particular emphasis is given on different methods of their preparations such as "step-growth polymerization" and "chain-growth polymerization" and ways to control their molecular weight.
3) As the properties of polymers largely depends on their structures, methods to make more complex topologies like copolymers, block copolymers, start polymers, graft copolymers, hyperbranched polymers etc. through various "living polymerization" techniques and others are thoroughly discussed.
4) Introduction to environment friendly "biodegradable polymers", their synthesis and signification in biomedical researches and making commodity plastics is also covered in this course.

Content:

Introduction to polymers (2 lectures): Natural polymers; synthetic polymers; structures of commonly used polymers; various terms (average molecular weight, number average, weight average, polydispersity index etc.) used in polymers literature.
Classification of polymers based on various parameters (1 lecture): Stereochemistry, structure,

crystallization nature etc.
Synthesis of polymers (2 lectures): Step growth polymerization- various polymerization reactions, control of molecular weight (mono-functional impurity, stoichiometric imbalance)
Chain polymerization (12 lectures): radical polymerization, mechanism, kinetics, reactivity ratios, various ring-opening polymerization, ionic polymerization, coordination polymerization, emulsion polymerization, precipitation polymerization. Introduction to controlled ("living") polymerization- ATRP, RAFT, NMP, GTP.
Branched polymers (2 lectures): Hyper-branched polymers, dendrimers.
Polymer Characterization (5 lectures): Thermal analysis (glass transition temperature, crystalline & melting temperature); Mechanical properties (Elastomers, fibres, thermoplastics, thermosetting, thermoplastic elastomers etc.); Determination of molecular weight (end group analysis by UV & NMR, GPC, viscosity).

Outcomes:
1) Polymer chemistry is today a very important topic of research for its wide applications across many fields. So, a dedicated course on this vast topic will be very beneficial for the students across different disciplines.
2) From this course, students will gain fundamental knowledge about various types of polymers and their uses and how to synthesize and characterize them.
3) More importantly, with the knowledge they gather from this course they can imagine to design new polymers for target specific applications.
4) This course will be highly advantageous for students who seek to pursue future research on polymer chemistry, biomedical research for designing drug delivery vehicles and soft matters in general.

AIS 4203 / CHS 4201: Thermodynamics and Statistical Mechanics

Content:

A. **Equilibrium Thermodynamics**
- Concept of thermodynamic equilibrium: Thermal, Mechanical and Chemical Equilibrium (2L)
- Formal relationships: Euler equation; Gibbs-Duhem relation (1L)
- Maximum work Theorem: Maximum Entropy an Minimum Energy principle (2L)
- Legendre transformation and thermodynamic potentials; Minimum principles of potential (3L)
- The Maxwell relations and simple applications (1L)
- Stability condition for thermodynamic potential (3L)
- First order phase transition; Clausius-Clapayron equation; Gibbs Phase rule (3L)
- Thermodynamics in the neighborhood of the critical point with emphasis on scaling and universality (3L)
- Thermodynamics of small systems: Emphasis on interfacial energy (NVT ensemble) (1L)

B. **Statistical Thermodynamics**
- Ensemble and Ensemble averages, Partition function and thermodynamic potential (2L)
- Electronic, translational, vibrational and rotational partition function for hetero and homo nuclear diatom (2L)
- Calculation of equilibrium constant and other applications of statistical methods (1L)

C. **Non-Equilibrium Thermodynamics**

Near Equilibrium Phenomenon:
- Conservation laws; entropy production and 2nd law of thermodynamics (3L)
- Flux and thermodynamic force; Phenomenological equations; Onsager‟s reciprocal relations (4L)
- Stationary states; states with minimum entropy production; GlansdorfPrigogine inequality (3L)
- Applications of laws of Irreversible Thermodynamics (2L)

Far From Equilibrium Phenomena:

• Oscillatory Reactions (2L)

AIS 4204 / CHS 4204: Group Theory and Molecular Spectroscopy

Content:

Symmetry and Group Theory: Symmetry as a mathematical concept; symmetry and physical properties of atoms, molecules and solid, symmetry, quantum mechanics and conservation laws. Symmetry in chemical sciences. (2LH)

Elements of group theory: Symmetry operations and their associated algebra. Group, subgroup, simple group, semi-simple group, point group. Properties of groups. Generating elements of a group. Elementary theory of representations of groups; transformation operators, function spaces, invariant subspaces. (4LH) Equivalent, reducible and irreducible representations. grand orthogonality theorem, other theorems/relations involving irreducible representations, character of a representation, character orthogonality theorem. The reduction of a representation; projection operators. Notations for character tables for point groups. Direct product group; direct product representation. Representations and quantum mechanics. The vanishing of integrals because of symmetry. (8LH)

Applications of group theory to bonding, structure and reactivity as well as other properties: Symmetry-adapted linear combinations (SALC) and applications to Huckel MO Theory for acyclic and cyclic molecules, MOs of small and medium-size molecules (e.g., benzene, MX6, etc Molecular vibrations (normal modes and normal coordinate analysis., Woodward-Hoffmann and FMO approaches to reactivity. Symmetry selection for transition states and reaction paths. (7LH)

AIS 4205-Laboratory

Content:

Polymer Synthesis and characterization

- Synthesis and characterization of a polymer by chain reaction
- Synthesis and characterization of a polymer by step growth route
- Electrochemical synthesis of a conducting polymer
- Determination of Lower Critical Solution Temperature of (LCST) of a polymer by absorption spectroscopy

Organic Electronics

- Thermoelectric Power Factor Measurement
- Dye Sensitized Solar Cell Preparation and Measurement
- Fabrication of Liquid crystal single pixel display
- Light Emitting Diodes Fabrications

SEC 4200: Seminar and Colloquium

Objectives:

1. Students will get the confidence to present in front of the audience
2. Students will learn communication skills to present the seminar
3. Students will acquire the time management skills

Outcomes:

1. Students demonstrate their confidence to present in front of the audience
2. Students will enhance the presentation and communication skills.
3. Students will get the idea about how to manage their time efficiently during the seminar.

M.Sc. in Chemistry (Semester-3)

AIS-5101: Macromolecules-II

Objectives:

1. The course is designed to give an overview of macromolecules and plastics.
2. It provides about several physical properties which are experienced by us in daily life.
3. It tries to link macromolecular science to soft matter.

Content:

Introduction to Polymers (2 lectures): Various kinds of polymers as well as terms used in polymers literature, thermoplastic and thermoset polymers. Average molecular weight and its distributions

Solution Properties (10 lectures): Osmometry, Light Scattering behaviors (Rayleigh & Mie), Factors and Zimm's plot, Guinier approximation, Porod Region, Concept of SAXS and SANS; Viscosity and Mark-Kuhn-Houwnik equation, Ultracentrifugation and Svedberg's equation; Flory-Huggin's theory, enthalpy and entropy of mixing, Polymer-solvent interaction. Concept of spinodal and bimodal phase.

Solids State Properties (7 lectures): Morphological, structural properties, thermal behaviors, glass Transition behaviors, degradation behaviors, structure-property relationship, solid state packing, macromolecular crystals, growth and kinetics.

Mechanical Properties (4 lectures): Stress-strain (static and dynamic), moduli, Maxwell's model, Voigt Model.

Rheological Properties (5 lectures): Basic terms and definitions, Modulous (storage or loss), Types of fluid and typical behaviors. Shear Thinning / thickening; Yield Stress, Cross model, Power law model and Sisko model; Viscoelastic behaviors and different type of Rheometers.

Electrical Properties (3 lectures): Electrical transport, conduction behaviors and effect of doping. Mott's model.

Dielectric Properties (1 lecture): Concept of dielectric behaviors and its applications with various polymers/plastics.

Outcomes:

Students attending the course are expected to

1. learn about the various type of polymers and plastics.
2. learn the structure-property relations of macromolecules and their components from a general perspective.
3. understand that macromolecular science is an interdisciplinary subject.

Generic Electives from other Schools (GE-1)

i) **CHS 5103C**: Supramolecular Chemistry: Principles and Applications
ii) **CHS 5103B**: Chemistry and Physics of Solids
iii) **MAS 5103**: Materials for Energy

AIS-5102: Drug Design and Delivery

Objectives:

1. Students learn about the development of a new drug with the basic principles of medicinal chemistry.
2. To teach chemistry and biology with respect to the drug development.
3. How drug is functions to treat a disease.
4. To teach about the pharmacokinetics and pharmacodynamics.

4. How a new drug is developed for the treatment of a new disease.

Content:

Principle of Drug Design: Process of drug discovery and development from the identification of novel drug targets to the introduction of new drugs into clinical practice; Drug development of rare diseases, Pros and cons. Lipinski's rule, lead identification, lead optimization, classification, prodrug design and applications, as well as structure-based drug design methods. Natural product inspired drug discovery, from basic science to clinical approval. Design of proteasome inhibitor and development of drug. (13 L)
Recent advances in the use of computational and combinatorial chemistry in drug design (3 L).

Overview of approaches for both ligand and target discovery such as similarity searching, pharmacophore modelling, QSAR, structure-based drug design. In relation to this, detail study of kinase enzymes and their function on ATP followed by the approach to design of small-molecule-based kinase inhibitors, development of drugs from basic science to clinical approval. Drug Delivery: Drug delivery systems; Solubility, Drug diffusion and dissolution, pH and drug action, Stability, and bioavailability. (12 L)

Outcomes:

Students will develop understanding regarding the procedure towards the drug development. They will be knowing what are the subjects and technologies are involved in drug development area.

AIS 5104: Fabrication and characterization of soft materials

Content:

Module-1 (8 lectures)
Optical Microscopy: Basic principles & limitations
Electron Microscopy: 1. Basic principles of electron interactions with atoms 2. Electron diffraction 3. Cyro TEM 4. Confocal microscopy, 5. Atomic force microscopy basics.
Module-2 (7 lectures)
General Introduction to Lithography; Lithography Techniques, Classification of Lithography Techniques- Top Down, Bottom up, combined techniques; Serial vs. Parallel Techniques. Soft Lithography: basics, key concepts, major techniques – Micro Contact Printing, Nano imprint Lithography, Hot Embossing, Replica Molding (REM), Micro Molding in Capillaries (MIMIC), Capillary Force Lithography (CFL), Polymer Bonding Lithography; Patterning of films coated on Curved Surfaces.
Module-3 (8 lectures)
Soft Lithography for patterning of inorganic (sol-gel) thin films, polymers and Hydrogels. Hydrodynamics of a free surface, Capillarity, Physical origin of Instability, Wetting and dewetting, Length Scales Analysis, Pattern Formation. Ordered pattern formation by template guided and confined dewetting, Dewetting of Bilayers and polymers.

AIS-5117: Polymer Processing

Content:

Classification of Polymer processing operations, Simple model flows worth example (5L)
Extrusion; single screw extrusion, twin screw extrusion, film processing (4L),
Molding based processes; injection molding, blow molding, compression molding and rotational moulding, compounding and mixing (8L),
Thermoforming, calendering, Reactive processing and reaction injection Molding (7L)

AIS 5121 : Organic Optoelectronics: Materials, Mechanisms and Devices

Objectives:

The ability to fine-tune the light emission and charge transport properties of organic conjugated materials create a plethora of applications that are impossible to replicate with silicon. The potential future applications are enormous including the devices that can bend, twist, and conform to any surface. The course will expose and equip the aspirant researchers with knowledge of structure-optical/electronic property relationship of conjugated materials from molecules to materials, concepts and fundamental physics of optoelectronic devices (Organic light-emitting devices, lasers, organic thin-film transistors, photovoltaics, and photodetectors), key-strategies to utilize organic materials as an active medium in these devices.

Content:

Electronic structure of organic molecules, key photophysical processes in organic molecules, exciton processes in organic solids, conduction in organic solids, working principles of light harvesting and light emitting devices.

1. Electronic structure of organic molecules: Molecules molecular orbitals, LCAO, bonding and antibondig orbitals, orbital hybridization, HOMO and LUMO levels, conjugated Molecules and molecular materials, Band Structure. (4 lectures)
2. Key photophysical processes in organic molecules: Excited states (absorption and emission, singlet and triplet states), rates of electronic transitions, transition moment, Frank-Condon Principle, Radiative and non-radiative transitions, Excited state kinetics. (4 lectures)
3. Exciton processes in organic solids: Excitons, Wannier-Mott exciton, charge-transfer exciton Frenkel exciton, exciton diffusion, and energy transfer. (4 lectures)
4. Conduction in organic solids: Electron transfer, carrier concentration versus mobility, carrier generation, hopping transport, mobility measurements, Traps. (4 lectures)
5. Working principles of light harvesting and light emitting devices: Organic light emitting devices, LASERs, organic thin film transistors, photovoltaics and photodetectors, (8 lectures)

Outcomes:

The expected outcome is to have a scientifically matured, technically skillful, and competent researcher capable of exploring and excel in any field of organic optoelectronics in their career. Understanding in the structure-property relationship and knowledge of the device physics will allow researchers to tailor-made materials or choose the materials for targeted applications. The exposure to the fundamentals and the advanced concepts of the device structure will allow researchers to innovate in device design and develop accessible and sustainable optoelectronic devices for a better tomorrow.

AIS 5189: Project with Seminar

AEC 5100: Scientific writing with ethics

M.Sc. in Chemistry (Semester-4)

AIS-5201: Supramolecular and Macromolecular Biomaterial

Objectives:

1) To provide a broad perspective on the suparamolecular and polymeric assembled systems in water
2) To introduce unique features of self-assembled systems as biomaterials
3) To describe representative self-assembled systems and their relevance in biological applications (drug delivery, antibacterial material tissue engineering etc)

Content:

Amphiphilic aggregates: Structure, packing, thermodynamics (4 lectures)
Engineered amphiphiles: Peptide amphiphiles, supra-amphiphiles, π-amphiphiles (3 lectures)
Gels: Supramolecular Gel/ Cross-linked gels- Formation, physical properties & application (3 lectures)
Amphiphilic polymers: Amphiphilic linear lock copolymers/ hyperbranched polymers/ dendrimers-aggregations, structural variation, techniques, stimuli-responsive amphiphilic polymer aggregates, multi-valent binding and implication (4 lectures)
Supramolecular polymers and biological application (3 lectures)
Biomedical applications of amphiphiles: Drug delivery, Gene delivery, protein delivery, cellular uptake, targeting, antibacterial material (5 lectures)
Polymer bio-conjugates: Polymer-protein, polymer-DNA, polymer-peptide, polymer-drug conjugates and other conjugates and relevance in biological application. (4 lectures).

Outcomes:

1) Students taking this course will be familiar about the challenges and opportunities in this interdisciplinary area
2) t will enable the students to take up research program in the broad area of supramolecular biomaterials
3)This course will enable students to imagine and design new polymeric and supramolecular systems for biological applications

Generic Electives from other Schools (GE-2)

1) MAS 5203: Semiconductor Devices and Electronics
ii) MAS 5205: Vacuum Science, Thin Films and Solar Cell Technology
iii) Available GE courses from SCS.

AIS 5214: Engineering and Speciality Polymers

Content:

Introduction to Engineering Polymers: An introduction to the history, recent developments, applications and processing of polymers;
Characteristics of thermoplastics engineering plastics such as - polycarbonates, polyamides, polyimides, Poly (benzimidazoles), polyphenylene oxide;
Liquid Crystalline Polymers; Poly(aryl ether ketone), Poly(ether ketone), Poly(aryl ether sulfone), poly(phenylene sulfides),
Polyacetals; Processing and applications of thermoplastic and thermosets engineering plastics; Characteristics of Speciality polymers such as - fluropolymer, silicone,
Conducting polymers and its applications
Polymeric hydrogels and applications in devices / biological areas.

AIS-5203: Liquid Crystals & Display

Objectives:
1. To give overview of display systems.
2. Various Liquid Crystalline phases.
3. Displays using Liquid Crystal's.
4. Applications of Liquid Crystal's.

Content:
Structure and classification of mesophases, Thermotropic and lyotropic liquid crystals; Different molecular order-nematic, smectic and cholesteric phases; Recent interests in liquid crystals; X-ray analysis of unoriented and oriented liquid crystals; Measurement of nematic order parameter by NMR; Polymer liquid crystals. Molecular theory of nematic liquid crystals, Molecular theory of smectic A liquid crystals Symmetry, structure and order parameter; Phase diagram of homologous series, McMillan's theory. Elastic continuum theory of liquid crystals, General expression of free energy of a deformed nematic liquid crystal; Franck's elastic constants; Distortion due to external electric or magnetic field; Freederickz's transition; The twisted nematic cell. Landau's theory of phase transition, Generalization of Landau's theory to liquid crystals; Fourth order and sixth order Landau expansion for studying N-I transition; de Gennes' Generalization to smectic phase; Critical fluctuation; Liquid crystal displays-Optical properties of on ideal helix, agents influencing the pitch; Basic principle of liquid crystal displays; Advantages of liquid crystal displays; Twisted nematic crystal and cholesteric liquid crystal displays; Discotic liquid crystals, Lyotropic liquid crystals.

Outcomes:
1. Fabrication of displays.
2. Use liquid Crystal's for fabrication of displays.
3. To know how to address displays.

AIS 5215: Colloids and Interface Science

Content:
Surface Tension, Adhesion and capillarity: Effects of confinement and finite size; Concepts of surface and interfacial energies and tensions; Apolar (van der Waals) and polar (acid-base) components of interfacial tensions Young-Laplace equation of capillarity; examples of equilibrium surfaces; multiplicity, etc. Stability of equilibrium solutions; Contact angle and Young's equation; Determination of apolar (van der Waals) and acid-base components of surface/interfacial tensions; Free energies of adhesion; Kinetics of capillary and confined flows
Mesoscale thermodynamics: Gibbs treatment of interfaces; concept of excess concentration; variation of interfacial tensions with surfactant concentration
Mesoscale phenomena in soft matter and applications: Adhesion, wetting, nucleation, flotation, patterning of soft material by self - organization and other techniques
Stability of nanoparticle dispersions: DLVO and DLVO like theories and kinetics of coagulation plus general principles of diffusion in a potential field/Brownian movement
Nanofluidics: Stability of thin (< 100 nm) films; self-organization in confined systems; meso-patterning Advanced and Functional Interfaces: Superhydrophobicity, functional coatings, structural colors, nano-adhesives; nanocomposites

AIS 5204: Advanced Energy Systems and Applications

Objectives:

- To teach students about photovoltaic the most important renewable energy resource (both indoor and outdoor)
- Teach about energy storage technologies and it's role in energy triangle
- Teach about electrochemical energy, supercpacitors and to compare them
- Give them brief idea about current energy scenario in photovoltaics and in storage.
- India's current position in the world in photovoltaics and in energy storage. Plans ahead and timeline to achieve the goals.

Content:

Photovoltaic Energy and Materials: Introduction to photovoltaic (PV) systems: Historical development of PV systems. Overview of PV usage in the world. Solar radiation and spectrum of sun. Geometric and Atmospheric effects on sunlight, Calculation of solar irradiance at surfaces. Solar concentrators

Silicon Solar cells, basics, First-Generation to third generation Solar Cells, Dye-Sensitized Solar Cells, Perovskite solar cells and ferroelectric photovoltaics, organic Photovoltaics, Materials development for photovoltaics.

Introduction to Electrochemical Energy Conversion: Electrochemical vs. conventional energy conversion routes. Types of electrochemical cells for energy conversion (galvanic and electrolytic). Examples of electrochemical technology in energy conversion: applications. Energy conversion related to materials conversion.

Batteries & Fuel Cells: Principle and types of fuel cell. Lithium ion battery. Hydrogen storage technologies. Principles of super capacitors, Micro batteries. Application areas. Integrated energy applications. Power conditioning.

Outcomes:

- Students will be up to date with the information regarding photovoltiacs and energy storage technologies
-Will know the role of energy storage and will know clearly the triangle of energy (in association with ESA-1 class)
-Will know about India's development in photovoltaic energy and energy storage technolgoies. Latest role of India in energy storage and world policies.
- Photovoltaics and energy storage in space research, health and treating medical emergencies
-Will have problem solving skills in chemical reactions for electrochemical energy storage, calculatin power factor in supercapacitors, calculating solar power etc.

AIS 4206: Chemistry of Biological Systems

Content:

Introduction to biochemistry (1L); Amino acids and proteins (2L); Carbohydrates (2L) ; Plasma membrane (2L); Enzymes (3L).
Introduction to metabolism (1L); Glycolysis; Glycogen metabolism (1L); Transport through membranes (1L); TCA cycle (1L); Electron transport and oxidative phosphorylation (1L).
Lipid metabolism (2L); Amino acid metabolism and metabolic pathways of nucleotides (4L).
Replication of DNA; Structure and synthesis of RNA – Transcription (2L); RNA and protein biosynthesis – translation; DNA sequencing; DNA synthesis; polymerase chain reaction. (3L)

AIS 5218: Molecular Machinery Basics

Objectives

- Introduction to nanoscale and macroscale machines
- Challenges of directed motion in nanoscale
- Molecular prototypes of nanoscale machines/machine components
- Introduction to molecular electronics
- Molecules as part of electronic circuits

Content:

1. Introduction and Basic concepts (4 lectures)
   - 1.1 Bottom up and top down approach in machinery, introduction to biological molecular machines
   - 1.2 Quantum effects & electrons in atoms, molecules and solids, quantum mechanical tunnelling

2. Molecule based machines and devices (10 lectures)
   - 2.1 Size dependent properties of matter, scaling laws
   - 2.2 Brownian motion, Diffusion (Fick's laws), Stoke's Einstein Equation
   - 2.3 Propulsion at nanoscale, Reynold's number
   - 2.4 Molecular analogues of mechanical machines
   - 2.5 Feynman's Ratchet, Energy for molecular machines
   - 2.6 Molecular recognition, Host-guest interaction, Self-assembly of molecules, Amphidynamic crystals
3. Molecular Electronics (12 lectures)
   - 3.1 Introduction: Recent past, the present and its challenges, future.
   - 3.2 Electron mobility and diffusion coefficient
   - 3.3 Overview of basic nanoelectronics, quantum and classical regimes of electron transport, Boltzman transport equation, Landauer's Transport equation, quantum electron transport, coherent tunnelling and sequential tunnelling.
   - 3.3 Molecular Electronic Components

   Molecular switches and complex molecular devices, polyphenylene based molecular wires and rectifying diode switches, Quantum Dots & Quantum wires, Single Electron Devices. Negative differential resistance (NDR), Coulomb blockade.
   - 3.4 Spintronics: Introduction, Overview, Spin filters, Spintronic devices and applications.

Outcomes:

Students attending the course are expected to

- Understand the differences in working principles of nanoscale and macroscale machines.
- Understand functions of simple molecular machine components synthesized artificially, like rotors, turnstiles, motors, switches, rotaxanes, catenanes etc.
- Understand concept of molecular electronics and nanoscale electronic transport.
- Identify features required for molecular electronic functions like switching, sensing, diodes, etc. and understand their working principles.
- Learn to search and read relevant research papers and learn presentation of scientific literature

AIS 5219: Advanced Simulations & Data Science

Content:

Programming Language:

Basic knowledge of C or Fortran 90 – Data statements, Logical and Arithmetic expressions, Operators, I-O

statements, Implementation of Loops, Control Statements, Functions and Subroutines, Array manipulation, Processing Strings and Characters, Format Specifications, File processing, Derived types, Pointers and Structure Data Type. Familiarization with Linux based operating system, development of simple C or Fortran programs, compilation and execution.

Numerical Method:
Root finding of equations having numerical coefficients using Successive Bi-section and Newton Raphson method, Basic ideas of Interpolation – Newton's forward and backward interpolation, Lagrange method for unequal intervals, Numerical integration of a definite integral using Trapezoidal and Simpson's one-third rule, Statistical Description of Data, Fast Fourier Transform, Fourier and Spectral Applications, Numerical solution for a set of coupled ordinary differential equation –, Initial Value Problem: Runge Kutta Method, (ii) Boundary Value Problem: Relaxation Technique, Shooting Method, Partial Differential Equations (PDE): (i) Elliptic PDE – Static Boundary Value Problems, (ii) Parabolic PDE – Time Evolution or Dynamic Initial Value Problems, (iii) Hyperbolic PDE – Wave Propagation Problem

AIS 5206 : Project with Seminar

SEC 5200: Seminar / Colloquium

Objectives:

1. Students will get the confidence to present in front of the audience
2. Students will learn communication skills to present the seminar
3. Students will acquire the time management skills

Outcomes:

1. Students demonstrate their confidence to present in front of the audience
2. Students will enhance the skill of the presentation and communication.
3. Students will get the idea about how to manage their time efficiently during the seminar.

M. Sc. in Biology (Semester-1)

AIS 4102: Biophys. and Biochem. Methods

Content:

Overview of modern biophysical and biochemical experimental techniques; Spectroscopy theory: Electromagnetic and quantum theory of radiation, wave particle duality, Light matter interaction, Transition dipole moment, Jablonsky diagram, Bear Lambert's Law. Spectroscopy - UV-visible, IR, fluorescence spectroscopy and circular dichroism (CD); Microscopy & Imaging - optical microscopy, confocal fluorescence microscopy, atomic force microscopy; Molecular interaction - fluorescence resonance energy transfer (FRET), surface plasmon resonance (SPR), isothermal titration calorimetry (ITC); Mass Spectrometry. Application in characterization of Bio molecules.

Analytical and preparative chromatographic separation techniques - general concepts, dynamics of zone migration, multi-component adsorption, chromatographic dispersion, linear and non-linear chromatography; liquid chromatographic techniques - size exclusion, ion exchange, affinity and reverse phase chromatography

AIS 4106: Advanced Cell Biology

Content:

Prokaryotic and eukaryotic cell organizations; intracellular compartments and transport: membrane bound organelles, protein sorting, and vesicular transport, secretory pathways, endocytosis pathways, phagocytosis and pinocytosis; cell communication: general principles of cell signaling, G-protein linked receptors and enzyme linked receptors; cytoskeleton: intermediate filaments, microtubules, and actin filaments, microtubule polymerization dynamics, dynamic instability and treadmilling, actin polymerization dynamics, cell crawling, contractile structures, actomyosin complex, muscle contraction, neurons, axons, dendrites, growth cone, inward transport and outward transport; motor proteins; the structure of eukaryotic chromosome; Overview of the cell cycle, mitosis, meiosis, and cytokinesis, animal cells and yeast cells division; cell cycle control: cell cycle check point, metaphase/anaphase transition, control of cell numbers in multi-cellular organisms and programmed cell death, cancer, anti-mitotic drugs; cytoskeletal diseases: microtubule dependent drugs and actin targeted drugs. Life cycle, evolution of pattern formation; Embryonic development – fertilization, early development, genetics of axis specification in Drosophila; Later embryonic development – central nervous system, development of the tetrapod limb; Metamorphosis, regeneration and aging.

AIS 4107: Advanced Molecular Biology

Content:

Genes, genomic organization & Replication of DNA: Introduction: Genome, Genomics Genome databases; Annotation of genome. Genome diversity. organization of genes in viruses, bacteria and eukaryotes. Complexity of eukaryotic genes and chromosomes, Chromosome structure and packaging of DNA into higher order structures. Comparison of replication in prokaryotes and eukaryotes.

DNA repair and RNA processing: DNA damage and repair; error-prone trans lesion; DNA synthesis. RNA processing: Modification of eukaryotic mRNA at the 5’ and the 3’ end, splicing introns, differential RNA processing.

DNA-dependent synthesis of RNA: Types of RNAs, DNA-dependent RNA polymerase, sigma factor, bacterial promoters, identification of DNA binding sites by DNA foot printing, the three stages of RNA synthesis, rho-dependent and rho-independent termination. Transcription in eukaryotes.
Proteins Synthesis & Regulation of gene expression
Features of the genetic code, RNA editing, the ribosome as a supramolecular machine. Principles of gene regulation. Regulation of gene expression in bacteria, lac operon and trp operon, induction of SOS response, synthesis of ribosomal proteins. Overview of regulation of gene expression in eukaryotes. Post-translational Protein interaction.

AIS 4108: Chemistry for Biologists

Objectives:

1) To teach basic organic chemistry and physical chemistry to Biology students
2) To introduce them various organic reactions involved in Bioconjugation
3) To introduce biological thermodynamics

Content:

Substitution and Elimination Reaction at Saturated Carbons: Basic mechanism and reaction profile, reaction kinetics, kinetic isotope effects, Saytzeff rules, Hofmann products; structure and reactivity of alkenes and alkynes, dienes, arenes. (5 lectures)
Carbonyl Chemistry: introduction to different types of carbonyl compounds (aldehydes and ketones, carboxylic acids and carboxylic acid derivatives (acid chlorides, acid anhydrides, esters and amides) and their reactivity with nucleophile; (5 lectures)
Basic reactivity of aromatic compounds with electrophiles and nucleophiles (2 lectures)
Structure elucidation of simple organic compounds by NMR spectroscopy, UV/Vis, Fluorescence, IR, CD spectroscopy and mass spectrometry (4 lectures)
Organic Reactions for Bioconjugation (2 lectures)
Acid-Base Reactions: Definitions (Brønsted, Lewis), pKa, trends in acid strength, Buffers (2 lectures)
Thermodynamics: The first law and conservation of energy, the second law and entropy; free energy and chemical equilibrium, phase equilibria and phase diagrams; Kinetics: rates of chemical reactions, enzyme kinetics; Transport in biological systems: diffusion, Fick's laws, viscosity (8 lectures)
Molecular structures and interactions: intermolecular forces and non-covalent interactions (2 lectures)

Outcomes:

1) It will enable Biology students to better understand various Chemical processes involved in biological systems
2) It will enable Biology students to learn the pros and cons of various biophysical studies
3) It will enable students to carry out basic organic reactions if necessary for research in the interface of Biology and Chemistry.

AIS-4105B: Laboratory

- Distribution assay of fluorescent probe in zebrafish embryos
- Evaluation of interaction between a protein and a drug
- Preparation of a hydrogel from well-known gelator and characterization (Tg by DSC, Rheology)
- Estimation of fluorescence QY (relative) of a organic fluorophore by external standard
- Preparation of a liposome from commercially available lipid and its characterization by DLS and TEM
- Co-encapsulation of donor and acceptor probe in liposome and probing by FRET (spectroscopy and microscopy)

- Estimation of minimum inhibitory concentration of a drug against a non-pathogenic bacterium
- MTT assay for cell viability of a known chemical compound

AEC 4100: Communicative English

M. Sc. in Biology (Semester-2)

AIS-4202: Macromolecules-1

Objectives:

1) It is an introductory course to polymer chemistry. In this course, students will gain knowledge about the historic origin of synthetic polymers, different classifications of polymers, their properties, characterization and uses.
2) Particular emphasis is given on different methods of their preparations such as "step-growth polymerization" and "chain-growth polymerization" and ways to control their molecular weight.
3) As the properties of polymers largely depends on their structures, methods to make more complex topologies like copolymers, block copolymers, start polymers, graft copolymers, hyperbranched polymers etc. through various "living polymerization" techniques and others are thoroughly discussed.
4) Introduction to environment friendly "biodegradable polymers", their synthesis and signification in biomedical researches and making commodity plastics is also covered in this course.

Content:

Introduction to polymers (2 lectures): Natural polymers; synthetic polymers; structures of commonly used polymers; various terms (average molecular weight, number average, weight average, polydispersity index etc.) used in polymers literature.
Classification of polymers based on various parameters (1 lecture): Stereochemistry, structure, crystallization nature etc.
Synthesis of polymers (2 lectures): Step growth polymerization- various polymerization reactions, control of molecular weight (mono-functional impurity, stoichiometric imbalance)
Chain polymerization (12 lectures): radical polymerization, mechanism, kinetics, reactivity ratios, various ring-opening polymerization, ionic polymerization, coordination polymerization, emulsion polymerization, precipitation polymerization. Introduction to controlled ("living") polymerization- ATRP, RAFT, NMP, GTP.
Branched polymers (2 lectures): Hyper-branched polymers, dendrimers.
Polymer Characterization (5 lectures): Thermal analysis (glass transition temperature, crystalline & melting temperature); Mechanical properties (Elastomers, fibres, thermoplastics, thermosetting, thermoplastic elastomers etc.); Determination of molecular weight (end group analysis by UV & NMR, GPC, viscosity).

Outcomes:

1) Polymer chemistry is today a very important topic of research for its wide applications across many fields. So, a dedicated course on this vast topic will be very beneficial for the students across different disciplines.
2) From this course, students will gain fundamental knowledge about various types of polymers and their uses and how to synthesize and characterize them.
3) More importantly, with the knowledge they gather from this course they can imagine to design new polymers for target specific applications.
4) This course will be highly advantageous for students who seek to pursue future research on polymer chemistry, biomedical research for designing drug delivery vehicles and soft matters in general.

AIS 4206: Chemistry of Biological Systems

Content:

Introduction to biochemistry (1L); Amino acids and proteins (2L); Carbohydrates (2L) ; Plasma membrane (2L); Enzymes (3L).
Introduction to metabolism (1L); Glycolysis; Glycogen metabolism (1L); Transport through membranes (1L); TCA cycle (1L); Electron transport and oxidative phosphorylation (1L).
Lipid metabolism (2L); Amino acid metabolism and metabolic pathways of nucleotides (4L).
Replication of DNA; Structure and synthesis of RNA – Transcription (2L); RNA and protein biosynthesis – translation; DNA sequencing; DNA synthesis; polymerase chain reaction. (3L)

AIS-4208: Infection and Immunity

Content:

An overview of immune system; Infectious organisms: viruses, bacteria, fungi, protozoa, helminths, prion etc.; Virulence factors and host susceptibility, entry and exit of pathogens; How pathogens escape innate and adaptive immune systems; Control of infectious diseases: vaccination, chemotherapy and public health measures.
Viral pathogenicity and antiviral agents; Case studies: HIV, influenza, swine flu etc., and recent viral outbreaks: Zika, Ebola, Chikungunya, bird flu etc.; bacterial diseases (Tuberculosis, Diphtheria, Staphylococcal infection etc) and immunity; Fungal (systemic and opportunistic infections) and protozoal (Malaria, Leishmaniasis etc.) diseases and immunity; Cancer immunology.

AIS 4209: Molecular Microbiology

Content:

Introduction to molecular microbiology; Health/economic significance of microorganisms; vertical and horizontal transfer of genetic materials in microbes; Transformation, conjugation and transduction; Culture-based and culture-independent molecular detection of microorganisms. Morphology and cellular architectures of microorganisms; Molecular basis of bacterial growth and division; Solute transport in bacteria: ABC transporters, amino acid transport, drug export systems etc.

Microbial interactions: environmental and quorum sensing. Microbe-host interactions. Biofilm formation and its implication, bacterial adhesion to host and pathogenesis; targeting strategies against cell wall biosynthesis, and other fundamental processes of bacteria; Mechanism of antibiotic action and resistance; Multidrug resistance, progress and challenges; Structure, function and virulence of viruses, and others microorganisms including fungus, protozoa and parasites. Comparative and environmental genomics.

AIS 4205B: Laboratory

Polymer Synthesis and characterization

- Determination of Lower Critical Solution Temperature of (LCST) of a polymer by absorption spectroscopy
- Studying controlled release of a drug from a polymeric aggregate
- Fluorescence live/ dead assay for probing integrity of cell membrane

- Demonstration of computer-aided drug discovery tools
- Enzyme Kinetics and Inhibition
- Transformation of E. coli using GFP plasmid
- Isolation of plasmid DNA from transformed colonies
- Agarose gel electrophoresis of isolated plasmid and DNA quantization / purity of DNA

SEC 4200: Seminar with Colloquium

Objectives:

1. Students will get the confidence to present in front of the audience
2. Students will learn communication skills to present the seminar
3. Students will acquire the time management skills

Outcomes:

1. Students demonstrate their confidence to present in front of the audience
2. Students will enhance the skill of presentation and communication.
3. Students will get the idea about how to manage their time efficiently during the seminar.

M. Sc. in Biology (Semester-3)

AIS-5102: Drug Design and Delivery

Objectives:

1. Students learn about the development of a new drug with the basic principles of medicinal chemistry.
2. To teach chemistry and biology with respect to the drug development.
3. How drug is functions to treat a disease.
4. To teach about the pharmacokinetics and pharmacodynamics.
4. How a new drug is developed for the treatment of a new disease.

Content:

Principle of Drug Design: Process of drug discovery and development from the identification of novel drug targets to the introduction of new drugs into clinical practice; Drug development of rare diseases, Pros and cons. Lipinski's rule, lead identification, lead optimization, classification, prodrug design and applications, as well as structure-based drug design methods. Natural product inspired drug discovery, from basic science to clinical approval. Design of proteasome inhibitor and development of drug. (13 L) Recent advances in the use of computational and combinatorial chemistry in drug design (3 L).

Overview of approaches for both ligand and target discovery such as similarity searching, pharmacophore modelling, QSAR, structure-based drug design. In relation to this, detail study of kinase enzymes and their function on ATP followed by the approach to design of small-molecule-based kinase inhibitors, development of drugs from basic science to clinical approval. Drug Delivery: Drug delivery systems; Solubility, Drug diffusion and dissolution, pH and drug action, Stability, and bioavailability. (12 L)

Outcomes:

Students will develop understanding regarding the procedure towards the drug development. They will be knowing what are the subjects and technologies are involved in drug development area.

Generic Electives from other Schools (GE-1)

i) BS 50007: Nanoscale Engineering of Biological Systems

ii) MAS 5103: Materials for Energy

iii)

AIS 5108: Computational Biology and Bioinformatics

Objectives:

1. The course is designed to give an overview of basic cell biology.
2. It tries to link biology to science other than biology

Content:

Vectors and Co-ordinate systems. Differentiation: Introduce change in concentration, length-scale etc. as derivatives. Relate slope and derivative. Integration: Integration as area under a curve. Integrating simple expressions. Use of Integration techniques in biology. Differential Equations: Ordinary/partial differential equations. Fourier transformation. Applications in biology. Stochasticity in biology: Introduction to probability and distribution functions, Gaussian and Poisson distribution, Examples from biology, Stochastic modeling of biopolymers, molecular motors. Descriptive statistics: Measurement scales, continuous and discrete data, Histograms, Mean, variance, standard deviation, Errors, fitting a function to experimental data, linear and nonlinear fits.

Biological Databases: Organisation, searching and retrieval of information, accessing global bioinformatics resources using internet links. Introduction to Unix operating system and network communication. Nucleic acids sequence assembly, restriction mapping, finding simple sites and transcriptional signals, coding region identification, RNA secondary structure prediction. Similarity and Homology, dotmatrix methods, dynamic programming methods, scoring systems, multiple sequence alignments, evolutionary relationships, genome analysis. Protein physical properties, structural properties – secondary structure prediction, hydrophobicity patterns, detection of motifs, structural database (PDB). Genome databases, Cambridge structure database, data mining tools and techniques, Structural Bioinformatics, Topics from the current literature will be discussed.

Outcomes:

1. Students learn the structure and functions of cells and their components from a general perspective.
2. Students understand that modern biology is an interdisciplinary subject.

AIS 5109 : Functional Materials in Biology

Content:

Introduction to Biomaterials, Biomineralization, Molecular Self-assembly, Nanomaterials (5L),
Synthetic and naturally derived biomaterials (2L),
Organic and inorganic polymers, proteins, polysaccharydes, composite biomaterials (6L)
Nanobiomaterials, Clinical applications, Decellularization, Hydrogels (5L),
Tissue engineering, Regenerative medicine, Biodegradable materials (5L)

AIS 5110: Pharmacokinetics and Pharmacogenomics

Content:

Pharmacology and toxicology:

1. Pharmacokinetics, pharmacodynamics, pharmacological effect, desired, undesired, toxic, adverse effects.
2. Bioavailability, bioequivalence, various factors of ADME
3. Drug metabolism: various pathways and other details.
4. Drug interactions, agonist, antagonist, partial agonist, protein binding, drug distribution, distribution volume, excretion pathways etc.

5. Mechanism of drug action, drug-receptor interaction.
6. Various adrenergic, cholinergic and other receptors
7. Detailed study of CNS pharmacology specially opiod receptors
8. Diseases: study of the pharmacology of the diseases and drugs used with mode of action especially of diabetes, malaria, leishmaniasis, TB, hypertension, myocardial ischemia, inflammation, and immunomodualtion.
9. Chemotherapy and pathophysiology- knowledge of antibiotics, their mode of action and the microorganisms responsible for various common diseases.
10. Bioassay methods, various requirements

Pharmaceutical analysis:
1. Stability testing of pharmaceuticals, various stability tests, kinetic studies, shelf life determination, thermal stability, formulation stability.
2. Various analytical techniques
3. Tests: physical and chemical tests, limit tests, microbiological tests, biological tests, disintegration and dissolution tests.
4. Thermal techniques: DSC, DTA, TGA, etc.
5. Chromatography- detailed.
6. QA and QC: GLP, TQM, ISO system.
7. Solubility: pH, pka, surfactant HLB values, Rheology.
8. Crystallinity, polymorphism, solvates and hydrates, crystal habits, porosity, surface area flow properties.
9. Dosage forms, Stages of dosage form development
10. Osmolality, osmolarity, osmotic pressure, conductivity,

Introduction to the human genome project and Pharmacogenomics
Describe the basic principles of genetics, such as single gene inheritance, independent assortment, linkage, and genetic variation.
Explain how the genome conveys information to the rest of the body (the central dogma of molecular biology).
Physical mapping and sequencing of genome, sequence analysis, comparative homologies, evolutionary changes and single nucleotide polymorphism, expression and analysis of expressed genes.
Relate genetic polymorphisms to the function of various types of proteins, their role in disease development and therapeutics.
Explain scientific procedures and techniques frequently performed in Pharmacogenomic research.

AIS 5119: Virology

Content:

Bacterial viruses (10 lectures):
Historical concept: discovery, phage assays, phage growth cycle
Molecular genetics of phage lambda:lytic-lysogeny decision making, repressor control, retro-regulation, temporal and topological aspects of gene regulation, recombination.
Molecular genetics of phage T4: Benzer's experiment to understand the unit of recombination and the concept of cistron. Host reappropriation strategies used by phage T4.
Phage defence mechanisms against viruses. Restriction modification, altruism, CRISPR
Animal virus (10 lectures):
Historical perspectives, origin of viruses, classification of animal viruses, Basic structure of animal viruses: capsid structures, envelops etc, RNA viruses , **+** Strand RNA virus : Coronavirus; - Strand RNA virus: Influenza; Retro virus : HIV; DNA virus: Adenovirus ; Host response to virus infection and vaccines.

AIS 5120: Synthetic Biology

Content:

Structure of, expression and regulation in prokaryotic and eukaryotic systems, including their viruses. Advanced biotechnological methods comprising cloning, mutagenesis, polymerase chain reaction, synthesis of nucleic acids, DNA sequence determination, synthetic genomics, CRISPR-Cas9, directed evolution, alternative splicing and computational modeling. Experimental characterization of structural and functional properties of biomolecules. Bioinformatic analysis and characterization of genes and biomolecules. Basic theoretical and computational modelling of replicating systems. Laboratory highlighting BioBrick cloning and chromoprotein reporters as a methodology in synthetic biology. Ethical aspects.

AIS 5105 /AIS 5189: Project with Seminar

AEC 5100: Scientific Writing and Ethics

M. Sc. in Biology (Semester-4)

AIS 5202: Disease Biology

Objectives:

1. Familiarise students with concepts of human health and disease
2. Providing information on the molecular basis of human diseases with emphasis on non-communicable diseases
3. Familiarise students with history of biomedical research and scope for future research

Content:

Introduction to the concepts of health and disease. Hallmarks of health. Introduction to tissue, tissue derangements (atrophy, hypertrophy, degeneration, hyperplasia etc) with pathogenesis and molecular basis. Tissue regeneration and related diseases (would healing as an example). Angiogenesis, its pathology and molecular mechanism. Introduction to cholesterol, fat and glucose metabolism. Metabolic diseases including diabetes, atherosclerosis, fatty liver disease and their cellular and molecular pathophysiology. Signal transduction in the context of disease biology (growth factor, Akt, AMPK, mTOR). Hallmarks of cancer and their molecular underpinnings.

Outcomes:

1. Students should be able to explain pathophysiology of human diseases in molecular terms
2. Students should be able to analytically solve problems related to disease process and outcome
3. Students should relate to the real-world health issues in society at large

Generic Electives from other Schools (GE-2)

i) BIS 4204: Stem Cell Biology and Therapy

AIS-5201: Supramolecular and Macromolecular Biomaterial

Objectives:

1) To provide a broad perspective on the suparamolecular and polymeric assembled systems in water
2) To introduce unique features of self-assembled systems as biomaterials
3) To describe representative self-assembled systems and their relevance in biological applications (drug delivery, antibacterial material tissue engineering etc)

Content:
Amphiphilic aggregates: Structure, packing, thermodynamics (4 lectures)
Engineered amphiphiles: Peptide amphiphiles, supra-amphiphiles, π-amphiphiles (3 lectures)
Gels: Supramolecular Gel/ Cross-linked gels- Formation, physical properties & application (3 lectures)
Amphiphilic polymers: Amphiphilic linear lock copolymers/ hyperbranched polymers/ dendrimers-aggregations, structural variation, techniques, stimuli-responsive amphiphilic polymer aggregates, multi-valent binding and implication (4 lectures)
Supramolecular polymers and biological application (3 lectures)
Biomedical applications of amphiphiles: Drug delivery, Gene delivery, protein delivery, cellular uptake, targeting, antibacterial material (5 lectures)
Polymer bio-conjugates: Polymer-protein, polymer-DNA, polymer-peptide, polymer-drug conjugates and other conjugates and relevance in biological application. (4 lectures).

Outcomes:
1) Students taking this course will be familiar about the challenges and opportunities in this interdisciplinary area
2) t will enable the students to take up research program in the broad area of supramolecular biomaterials
3)This course will enable students to imagine and design new polymeric and supramolecular systems for biological applications

AIS 5208: Biomaterials and Tissue Engineering

Content:
Basic concepts: General overview of components in the human body used to construct tissue. Implantable materials: temporaryl or permanent implants, biodegradable materials, cell substrates, tailored tissue. Bioactive materials and drug delivery systems. Protein surface interactions. Interactions between human tissue and biomaterials: properties at natural tissue and transplantation techniques. Tissue Engineering and regenerative medicine. Biomimetic systems. Sterilisation. Evaluation procedures for medical devices.

AIS 5209: Neurophysiology

Content:
Nerve-Muscle Physiology: Neuron structure and function; Regeneration of nerve;;Axoplasmic flow and transport mechanism in the axons; Nature of nerve fibre excitation and interpretation of action potential; Significance of different nerve fibre types. Structural architecture of Neuro-Muscular Junction (NMJ); Neuromuscular transmission - Electrical and Biochemical events; Drugs acting at NMJ. Protein components and contraction mechanism of muscles. B. Nervous System: Interpretative function of cerebral cortex. Aging and its effect on brain, Regulatory function of cerebellum and structure activity relationship (neural circuitory) of cerebellum, Vestibular apparatus, hypothalamus and its functions, basal ganglia, thalamo cortical projections. Non-specific sensory mechanism- Sleep and wakefulness. Behavioural functions of the brain - emotion, memory, learning and consciousness, Pharmacology and chemical transmission autonomic nervous system. C. Special Sense: Sensory modalities, Sensory receptors, Sensory circuits, and Sensory perception. Taste system, Olfactory system, Visual Sense and Auditory Senses.

AIS 5210: Nanobiotechnology

Content:
1) Role of nanometer length scale in biology: (4 lectures)
Natural system having nanoscale components, examples of biochemical activities at nanoscale, biomolecular self-assembly, macromolecular crowding effect

2. Nanobioconjugates: (10 lectures)
Synthetic and naturally derived nanomaterials, Preparation and characterization of nanobioconjugates, some commercial nanobioconjugates.

3) Functional nanomaterials in biology: (6 lectures)
Synthetic and naturally derived nanomaterials, reactive oxygen species generating nanomaterials, molecular imprinted nanocomposite, nanoparticle for autophagy upregulation, designed nanomaterials for active and passive targeting and blood-brain barrier crossing

4) Medical use of nanoparticle: (8 lectures)
Nanoparticle in drug delivery and photodynamic therapy, designing nanoparticle to control intracellular processes, targeted drug delivery systems, application of nanoparticle in medical imaging, nanomaterials-based inhibition of amyloid aggregation using protein and cell model.

AIS-5216: Gene Therapy

Content:

Fundamental understanding of gene therapy, in-depth look at important trends, various materials and advances in gene therapy. Human Disease Targeted for Gene therapy, Antigene and Antisense Therapy, Vector and other Delivery Systems for Gene therapy, Viruses as vector, on viral DNA Delivery systems, Synthetic particles and nanotechnology for drug Targeting and Gene therapy, Ex vivo vs In vivo Gene Therapy. Genetically modified stem cells in experimental gene therapy.

AIS-5217: Epigenetics

Content:

Histone code, chromatin associated proteins, the formation and maintenance of heterochromatin, experimental methods, and model organisms. Role of epigenetics in biological phenomena such as imprinting, X-inactivation, cellular identity, cellular reprogramming, tumorigenesis, and the onset of certain types of neurological disorders

AIS 5206: Project with seminar

SEC 5200: Seminar / Colloquium

Objective

1. Students will get the confidence to present in front of the audience
2. Students will learn communication skills to present the seminar
3. Students will acquire the time management skills

Outcome

1. Students demonstrate their confidence to present in front of the audience
2. Students will enhance the skill of presentation and communication.
3. Students will get the idea about how to manage their time efficiently during the seminar.

M. Sc. in Physics (Semester-1)

AIS 4110 / PH 4101: Classical Mechanics

Content:

Newton's laws, generalised co-ordinates. Lagrange's principle of least action and equations. Conservation laws and symmetry. Integrable problems, elastic collisions and scattering. Small oscillations including systems with many degrees of freedom, rigid body motion. Hamilton's equations. Poisson brackets. Hamilton Jacobi theory. Canonical perturbation theory, Chaos.

AIS 4111 / PH 403: Quantum Mechanics-I

Content:

Vector spaces, linear operators, eigenvalue problems; postulates of quantum mechanics, Heisenberg uncertainty relations; time evolution; Schroedinger equation; harmonic oscillator; creation and annihilation operators; One dimensional problems – bound states, tunneling, scattering. The harmonic oscillator, analytical and operator approaches. Three dimensional problems. Symmetries, conservation laws, degeneracies, with examples. Infinitesimal rotations, angular momentum operators, commutation relations and their consequences. Separation of variables for a central force problem. Spherical harmonics. The hydrogen atom. Time independent perturbation theory, non-degenerate and degenerate cases. Fine and hyperfine structure of energy levels. Stark and Zeeman effects.

AIS 4112 / PH405: Mathematical Methods-I

Content:

Vectors: Definitions, dot product, cross product, vector fields, Differentiation, line integrals, surface integrals, Divergence Theorem, Stokes Theorem, Tensors(qualitative concepts), summation convention and co-ordinate transformation. Curvilinear Coordinates. Linear algebra and Vector spaces: Matrices, Rank of a Matrix, Complex Inner Product Spaces, Orthogonal and Unitary Transformations, Eigenvalues and Eigenvectors and application, Change of Basis, Diagonalization of Matrices. Function spaces; Hilbert spaces; orthogonal expansions; operators in infinite dimensional spaces, Fourier series and Fourier transform, generalized functions; Dirac delta function, Differential equation: Methods of solution, Laplace transformation method, Power series method, Fourier expansion methods. Orthogonal polynomials: Orthogonal polynomials, Legendre and Hermite polynomials, Sturm-Liouville Theory, Eigenfunction Expansions. Elements of statistics: probability, random walk. Probability distributions

AIS 4113: Electronics

Objectives:

1. Students will get the knowledge and know-how about the essential electronic devices in their daily life applications.
2. Students will learn to understand device physics.
3. Students will visualize charge carrier movement inside the devices

Content:

Analog circuits: (3 hours):

Superposition, Thevenin, Norton and Maximum Power Transfer Theorems, Network elements, Laplace, Fourier and Z – transforms. Time and frequency domain responses. Imageimpedance and passive filters. Two – port Network Parameters. Transfer functions, Signal representation. State variable method of

circuit analysis, AC circuit analysis, Transient analysis.
Semiconductor Physics: (18 hours)
Concepts of solid-state physics, Band theory, Metal semiconductor junctions: Schottky barriers; Rectifying contacts; Ohmic contacts; Typical Schottky Barriers, semiconductor devices and their operations: Tunnel diode; Photodiode; Solar cell; LED; LDR; p-n-p-n switch, SCR; Unijunction transistor (UJT); Programmable Unijunction transistor (PUT), Solid state detectors (Si and HPGe).Electronic Transport in semiconductor, PN Junction, Diode equation, Tunnel diode, characteristics and equivalent circuits of BJT, JFET, MOSFET,
Device Applications: (9 hours)
Biasing of Bipolar junction transistors and JFET. Single stage amplifiers, Multistage amplifiers, Feedback in amplifiers, oscillators, function generators, multivibrators, Operational Amplifiers (OP AMP) – characteristics and Applications, Computational Applications, Wave shaping circuits, Active filters, Schmitt trigger, Phase locked loop.
Digital Circuits: (6 hours)
Logic families, flip – flops, Gates, Boolean algebra and minimization techniques, Multivibrators and clock circuits, Counters-Ring, Ripple. Synchronous, Asynchronous, Up and down shift registers, multiplexers and demultiplexers, Arithmetic circuits, Memories, A/D and D/A converters.

Outcomes:
1. Students learnt the working principle of electronic devices.
2. Students will get the thinking capability to design new electronic devices according to the requirement.
3. Students will pick up the basic idea about electronic devices.

AIS-4105P: Laboratory

- Preparation of a liposome from a commercially available lipid and it characterization by DLS and TEM
- Preparation of a surfactant micelle and determination of CMC by fluorescence probe
- Preparation of a hydrogel from well-known gelator and characterization (Tg by DSC, Rheology)
- Preparation of nano-material based photonic crystals
- Determination of phase transitions of a organic small molecule liquid crystal by DSC and POM
- Estimation of fluorescence QY (relative) of a organic fluorophore by external standard
- Contact angle measurement experiment of a polymer coated surface
- Thermodynamics and Kinetics of Phase Transformations Experiment

AEC 4100: Communicative English

M. Sc. in Physics (Semester-2)

AIS 4210: Statistical mechanics

Content:
Review of Thermodynamics, Basic principles of statistical mechanics and its application to a few simple systems. Probability theory, fundamental postulate, phase space, Liouville's theorem, ergodicity, microcanonical ensemble, connection with thermodynamics, canonical ensemble, classical ideal gas, harmonic oscillators, paramagnetism, Ising model, physical applications to polymers, biophysics. Grand canonical ensemble, thermodynamic potentials, Maxwell relations, Legendre transformation, introduction to quantum statistical mechanics, Fermi, Bose and Boltzmann distribution, Bose condensation, photons and phonons, Fermi gas, classical gases with internal degrees of freedom, fluctuation, dissipation and linear response, Monte Carlo and molecular dynamics methods.

AIS 4211: Electromagnetic Theory

Content:

Coulomb law and electrostatics, Laplace and Poisson equations, uniqueness theorem, boundary-value problems, method of images, dielectrics, steady currents; and magnetostatics, time-varying fields, Maxwell's equations, electromagnetic waves, partial polarization, Lorentz force, Poynting theorem. Gauge transformations and gauge invariance, electromagnetic potentials, wave propagation in conductors and dielectrics, Lorentz theory of dispersion, complex refractive index

AIS 4212: Soft Matter Physics

Introduction to soft matter (2): What is soft matter? Polymers (bio), Colloids, Surfactants, Liquid crystals, Granular Materials, Biological Materials

Soft matter properties and interactions (4): Thermodynamics of soft matter solutions, Equilibrium properties, Phase separation

Ionic soft-matter (2): Poisson-Boltzmann theory, Debye-Huckel approximation

Brownian motion and thermal fluctuations (4): Diffusion, Ficks Law, Brownian Motion, random Walk Langevin equation, Fluctuation dissipation theorem

Liquid interfaces (4): Surface tension, Wetting, Laplace pressure,

Introduction to polymers (3): Ideal-chain model, Worm-like chain model

Elasticitc soft matter (3): Polymer solutions and polymer gels, Elasticity of polymer chain.

Rheology and Viscous Flow of soft matter (4): Mechanical properties of soft matter, Viscoelasticity of polymer gel

AIS 4213: Advanced Device Physics

Content:

Module-1: (10-Lectures)

Crystal Properties of semiconductor materials, Quantum Mechanical aspects of crystalline solids, Quantum-Effect Devices, quantum wells, tunneling. Gunn effect and related devices. Impact ionization and avalanche processes in the junction. Avalanche gain. Ballistic injection devices. Hot electron transistors. Transferred-Electron and Real-space transfer devices. Basics of Heterojunctions, Modulation doped heterostructures. 2D electron gas formation, interface sheet carrier concentration.

Module-2: (8-Lectures)

(Basics of) - transistors for high-speed logic, transistors for high frequency (RF), transistors for high power switching. Gate leakage current. Low-noise amplifiers. Nonlinearity. RF characteristics. Heterostructure field-effect transistors (HFET). Monolithic microwave and millimeter integrated circuits. Hybrid vs. monolithic approaches.

Module-3: (8-Lectures)

Solar cells: principle, efficiency, Fill factor, Shockley-Quiesser limit, silicon solar cells, multi-junction solar cell. LEDs: working principle, radiative/non-radiative recombination, various types of efficiencies. Lasers: Device Structure, fundamental principles of light amplification in a solid-state device. Resonant cavities, and diode design for population inversion. Photonic devices, Photonic Integrated Circuits.

AIS 4205P: Laboratory

Content:

Organic Electronics

- Thermoelectric Power Factor Measurement
- Dye Sensitized Solar Cell Preparation and Measurement
- Fabrication of Liquid crystal single pixel display
- Light Emitting Diodes Fabrications

Polymer Synthesis and characterization

- Synthesis and characterization of a polymer by chain reaction
- Synthesis and characterization of a polymer by step growth route
- Electrochemical synthesis of a conducting polymer
- Determination of Lower Critical Solution Temperature of (LCST) of a polymer by absorption spectroscopy

SEC 4200: Seminar and Colloquium

M. Sc. in Physics (Semester-3)

AIS-5101: Macromolecules-II

Objectives:

1. The course is designed to give an overview of macromolecules and plastics.
2. It provides about several physical properties which are experienced by us in daily life.
3. It tries to link macromolecular science to soft matter.

Content:

Introduction to Polymers (2 lectures): Various kinds of polymers as well as terms used in polymers literature, thermoplastic and thermoset polymers. Average molecular weight and its distributions

Solution Properties (10 lectures): Osmometry, Light Scattering behaviors (Rayleigh & Mie), Factors and Zimm's plot, Guinier approximation, Porod Region, Concept of SAXS and SANS; Viscosity and Mark-Kuhn-Houwnik equation, Ultracentrifugation and Svedberg's equation; Flory-Huggin's theory, enthalpy and entropy of mixing, Polymer-solvent interaction. Concept of spinodal and bimodal phase.

Solids State Properties (7 lectures): Morphological, structural properties, thermal behaviors, glass Transition behaviors, degradation behaviors, structure-property relationship, solid state packing, macromolecular crystals, growth and kinetics.

Mechanical Properties (4 lectures): Stress-strain (static and dynamic), moduli, Maxwell's model, Voigt Model.

Rheological Properties (5 lectures): Basic terms and definitions, Modulous (storage or loss), Types of fluid and typical behaviors. Shear Thinning / thickening; Yield Stress, Cross model, Power law model and Sisko model; Viscoelastic behaviors and different type of Rheometers.

Electrical Properties (3 lectures): Electrical transport, conduction behaviors and effect of doping. Mott's model.

Dielectric Properties (1 lecture): Concept of dielectric behaviors and its applications with various polymers/plastics.

Outcomes:

Students attending the course are expected to

1. learn about the various type of polymers and plastics.
2. learn the structure and functions of macromolecules and their components from a general perspective.
3. understand that macromolecular science is an interdisciplinary subject.

Generic Electives from other Schools (GE-1)

i) MAS 5103: Materials for Energy
ii) CHS 5151/ PHS 503: Atomic and Molecular Sciences
iii) CHS 5103B: Chemistry and Physics of Solids

AIS 5106: Energy Generation and Harvesting Technologies

Objectives:
- To teach students about all different energy sources in perspective of world's energy need with low carbon footprint (both conventional and unconventional)
- Teach the motivation behind energy research, 2015 UN paris agreement for energy goal, energy policies, role of stakeholders
- Teach all about waste energy harvesting technologies
- Physics and Chemistry of Energy, Matter and Devices
- Given students brief idea about future technological and applications goals and opportunities lying in every technologies. India's energy scenario (research, applications and development)

Content:

Overview of energy Cycle and components. Nonrenewables: Fossil fuels, nuclear (fission, fusion). Energy usage, policies and sustainable energy goals. Energy Generation, and Harvesting Fundamentals (3L).

Renewable Energy Generation Technologies: wind, wave, tidal, solar, biomass, geothermal, hydropower etc. Environmental aspects and technological challenges (5L).

Harvesting of energies via solar, heat, vibration, magnetic, wind, wave, geothermal energy, biomass and tidal power technologies (6L).

Recent materials and methods for energy generation and harvesting. Nanotechnology in energy. Strategies to improve energy efficiency, conserve or harvest waste energies for reducing environmental impact. Goals towards an energy efficient sustainable future. Latest trends in energy research (8L).

Outcomes:
- Students will be up to date with the information regarding energy and sustainable applications
-Will know detailed research topics in energy and their role in mitigating energy crisis
-Will know about India's development in energy sector (both applications and R&D)
- Will have basic understanding of the physics of energy, thermodynamic principals, units, problems with solutions, energy material and their use in devices
-Will have clear idea about the future need in energy, how to move in that direction and possible outcome.

AIS 5112 / PH505: Condensed Matter Physics

Content:

Drude model, Sommerfeld model, crystal lattices, reciprocal lattice, x-ray diffraction, Brillouin zones and Fermi surfaces, Bloch's theorem, nearly free electrons, tight binding model, selected band structures, semiclassical dynamics of electrons, measuring Fermi surfaces, cohesive energy, classical harmonic crystal, quantum harmonic crystal, phonons in metals, semiconductors, diamagnetism and paramagnetism, magnetic interactions. Superconductivity

AIS 5114: Physics of Materials / Nanomaterials

Content:

Introduction to material science; building crystals from atoms, structure property relationship,

Electronic structure and phonons, Stability of structures: (a) thermodynamic stability (b) dynamic stability, Material properties: Mechanical; electrical; optical; magnetic and thermal, Defects, non-crystalline solids and finite structures.

Types of materials: Metals, semiconductors, ceramics, polymers, composites, multi-functional materials.

Characterization techniques: Experimental: X-ray & neutron diffraction, electron microscopy, scanning probe microscopy, spectroscopy and surface analysis, techniques, optical spectroscopy, magnetic spectroscopy

Computational: multi-scale modelling

AIS 5116: Magnetic Properties of Solids

Content:

Diamagnetism and Paramagnetism**:** Basic concepts, Hund's rule, Electronic magnetism, Classical and quantum theory of magnetism, Curie Law, Pauli and van Vleck paramagnetism.

Crystal Field: Octahedral and tetrahedral environment, low spin vs high spin, quenching of orbaital momentum, Jahn-Teller effect.

Ferromagnetism: Mean field theory, Curie-Weiss Law, Landau theory, band model, magnetic dipolar interactions, Direct and indirect exchange interactions

Antiferromagnetism & Ferrimagnetism: Different antiferromagnetic orders, Frustration, Neel model, Ferrimagnets.

Nanoscale Magnetism: Fundamental length scale, Sharp anisotropy, Single domain particles, Superparamagnetism, Blocking temperature, Effects if inner particle interaction and surface effects

Magnetic Resonance: ESR, NMR and hyperfine field

Experimental Methods: Low and high temperature magnetic field, VSM, SQUID

Biomagnetism: Microscopic origin of magnetic field inside human body, imaging techniques

AIS 5104: Fabrication and characterization of soft materials

Content:

Module-1 (8-Lectures)

Optical Microscopy: Basic principles & limitations

Electron Microscopy: 1. Basic principles of electron interactions with atoms 2. Electron diffraction 3. Cyro TEM 4. Confocal microscopy, 5. Atomic force microscopy basics.

Module-2 (7-Lectures)

General Introduction to Lithography; Lithography Techniques, Classification of Lithography Techniques-Top Down, Bottom-up, combined techniques; Serial vs. Parallel Techniques. Soft Lithography: basics, key concepts, major techniques – Micro Contact Printing, Nanoimprint Lithography, Hot Embossing, Replica Molding (REM), Micro Molding in Capillaries (MIMIC), Capillary Force Lithography (CFL), Polymer Bonding Lithography; Patterning of films coated on Curved Surfaces.

Module-3 (8-Lectures)

Soft Lithography for patterning of inorganic (sol-gel) thin films, polymers, and Hydrogels. Hydrodynamics of a free surface, Capillarity, Physical origin of Instability, Wetting and dewetting, Length Scales Analysis,

Pattern Formation. Ordered pattern formation by template guided and confined dewetting, Dewetting of Bilayers and polymers.

AIS 5121 : Organic Optoelectronics: Materials, Mechanisms and Devices

Objectives:

The ability to fine-tune the light emission and charge transport properties of organic conjugated materials create a plethora of applications that are impossible to replicate with silicon. The potential future applications are enormous including the devices that can bend, twist, and conform to any surface. The course will expose and equip the aspirant researchers with knowledge of structure-optical/electronic property relationship of conjugated materials from molecules to materials, concepts and fundamental physics of optoelectronic devices (Organic light-emitting devices, lasers, organic thin-film transistors, photovoltaics, and photodetectors), key-strategies to utilize organic materials as an active medium in these devices.

Content:

Electronic structure of organic molecules, key photophysical processes in organic molecules, exciton processes in organic solids, conduction in organic solids, working principles of light harvesting and light emitting devices.

1. Electronic structure of organic molecules: Molecules molecular orbitals, LCAO, bonding and antibondig orbitals, orbital hybridization, HOMO and LUMO levels, conjugated Molecules and molecular materials, Band Structure. (4 lectures)
2. Key photophysical processes in organic molecules: Excited states (absorption and emission, singlet and triplet states), rates of electronic transitions, transition moment, Frank-Condon Principle, Radiative and non-radiative transitions, Excited state kinetics. (4 lectures)
3. Exciton processes in organic solids: Excitons, Wannier-Mott exciton, charge-transfer exciton Frenkel exciton, exciton diffusion, and energy transfer. (4 lectures)
4. Conduction in organic solids: Electron transfer, carrier concentration versus mobility, carrier generation, hopping transport, mobility measurements, Traps. (4 lectures)
5. Working principles of light harvesting and light emitting devices: Organic light emitting devices, LASERs, organic thin film transistors, photovoltaics and photodetectors, (8 lectures)

Outcomes:

The expected outcome is to have a scientifically matured, technically skillful, and competent researcher capable of exploring and excel in any field of organic optoelectronics in their career. Understanding in the structure-property relationship and knowledge of the device physics will allow researchers to tailor-made materials or choose the materials for targeted applications. The exposure to the fundamentals and the advanced concepts of the device structure will allow researchers to innovate in device design and develop accessible and sustainable optoelectronic devices for a better tomorrow.

AIS 5105P: Project with Seminar

AEC 5100: Scientific Writing and Ethics

M. Sc. in Physics (Semester-4)

AIS 5203-Liquid Crystals & Display

Objectives:

1. To give overview of display systems.
2. Various Liquid Crystalline phases.
3. Displays using Liquid Crystal's.
4. Applications of Liquid Crystal's.

Content:

Structure and classification of mesophases, Thermotropic and lyotropic liquid crystals; Different molecular order-nematic, smectic and cholesteric phases; Recent interests in liquid crystals; X-ray analysis of unoriented and oriented liquid crystals; Measurement of nematic order parameter by NMR; Polymer liquid crystals. Molecular theory of nematic liquid crystals, Molecular theory of smectic A liquid crystals Symmetry, structure and order parameter; Phase diagram of homologous series, McMillan's theory. Elastic continuum theory of liquid crystals, General expression of free energy of a deformed nematic liquid crystal; Franck's elastic constants; Distortion due to external electric or magnetic field; Freederickz's transition; The twisted nematic cell. Landau's theory of phase transition, Generalization of Landau's theory to liquid crystals; Fourth order and sixth order Landau expansion for studying N-I transition; de Gennes' Generalization to smectic phase; Critical fluctuation; Liquid crystal displays-Optical properties of on ideal helix, agents influencing the pitch; Basic principle of liquid crystal displays; Advantages of liquid crystal displays; Twisted nematic crystal and cholesteric liquid crystal displays; Discotic liquid crystals, Lyotropic liquid crystals

Outcomes:

1. Fabrication of displays.
2. Use liquid Crystal's for fabrication of displays.
3. To know how to address displays.

Generic Electives from other Schools (GE-2)

i) **PHS 5206**: Light-Matter Interactions
ii) **PHS 4202**: Mathematical Methods-II
iii) **MAS 5203**: Semiconductor Devices and Electronics
iv) **MAS 5205**: Vacuum Science, Thin Films and Solar Cell Technology
v) **COM 4203**: Introduction to Machine Learning

AIS-5207: Physics and Chemistry of Fluids

Objectives:

1. Students will get the knowledge and know-how about the colloidal systems
2. Students will learn about the energies and dynamics involved in fluids
3. Students will visualize colloidal particles movement inside a solution

Content:

Surface and colloid systems, Thermodynamics of interface. Surface tension, Monolayer formation. LB layer. Self-assembled monolayer, Wetting. Contact angle, Surface free energy, Adsorption, Surface active agent: Surfactant in solution, Surface active agent: Application of surfactant, Dispersion systems: Sedimentation. Rheology, Electrokinetics phenomena: The electro double layer, Zetapotential-Double

layer interaction (DLVO theory), Normal stress, stress growth; Yield stress fluids - Hershel Belkley model, thixotropic fluids - Structural MODEL; Terms in nonlinear models; Microscopic origin of stress Adsorption of polymer. Stability and flocculation of colloids using polymer, Synthesis for colloidal systems, The supplementary lecture: Solution chemistry, Electrical chemistry.

Outcomes:

1. Students learnt the concepts behind the motion of the particles inside a solution
2. Students got the thinking capability to design the suitable colloidal solution
3. Students got the basic idea about the stability of colloids

AIS 5204: Advanced Energy Systems and Applications

Objectives:

- To teach students about photovoltaic the most important renewable energy resource (both indoor and outdoor)
- Teach about energy storage technologies and it's role in energy triangle
- Teach about electrochemical energy, supercapacitors and to compare them
- Give them brief idea about current energy scenario in photovoltaics and in storage.
- India's current position in the world in photovoltaics and in energy storage. Plans ahead and timeline to achieve the goals.

Content:

Photovoltaic Energy and Materials: Introduction to photovoltaic (PV) systems: Historical development of PV systems. Overview of PV usage in the world. Solar radiation and spectrum of sun. Geometric and Atmospheric effects on sunlight, Calculation of solar irradiance at surfaces. Solar concentrators

Silicon Solar cells, basics, First-Generation to third generation Solar Cells, Dye-Sensitized Solar Cells, Perovskite solar cells and ferroelectric photovoltaics, organic Photovoltaics, Materials development for photovoltaics.

Introduction to Electrochemical Energy Conversion: Electrochemical vs. conventional energy conversion routes. Types of electrochemical cells for energy conversion (galvanic and electrolytic). Examples of electrochemical technology in energy conversion: applications. Energy conversion related to materials conversion.

Batteries & Fuel Cells: Principle and types of fuel cell. Lithium ion battery. Hydrogen storage technologies. Principles of super capacitors, Micro batteries. Application areas. Integrated energy applications. Power conditioning.

Outcomes:

- Students will be up to date with the information regarding photovoltiacs and energy storage technologies
-Will know the role of energy storage and will know clearly the triangle of energy (in association with ESA-1 class)
-Will know about India's development in photovoltaic energy and energy storage technolgoies. Latest role of India in energy storage and world policies.
- Photovoltaics and energy storage in space research, health and treating medical emergencies
-Will have problem solving skills in chemical reactions for electrochemical energy storage, calculation

power factor in supercapacitors, calculating solar power etc.

AIS 5211: Nanoscale Materials

Content:

Introduction to different nanosystems and their realization; electronic properties of quantum confined systems: quantum wells, wires, nanotubes and dots. Optical properties of nanosystems: excitons and plasmons; photoluminescence, absorption spectra, vibrational and thermal properties of nanosystems; zone folding

AIS 5218: Molecular Machinery Basics

Objectives

- Introduction to nanoscale and macroscale machines
- Challenges of directed motion in nanoscale
- Molecular prototypes of nanoscale machines/machine components
- Introduction to molecular electronics
- Molecules as part of electronic circuits

Content:

1. Introduction and Basic concepts (4 lectures)
   - 1.1 Bottom up and top down approach in machinery, introduction to biological molecular machines
   - 1.2 Quantum effects & electrons in atoms, molecules and solids, quantum mechanical tunnelling

2. Molecule based machines and devices (10 lectures)
   - 2.1 Size dependent properties of matter, scaling laws
   - 2.2 Brownian motion, Diffusion (Fick's laws), Stoke's Einstein Equation
   - 2.3 Propulsion at nanoscale, Reynold's number
   - 2.4 Molecular analogues of mechanical machines
   - 2.5 Feynman's Ratchet, Energy for molecular machines
   - 2.6 Molecular recognition, Host-guest interaction, Self-assembly of molecules, Amphidynamic crystals

3. Molecular Electronics (12 lectures)
   - 3.1 Introduction: Recent past, the present and its challenges, future.
   - 3.2 Electron mobility and diffusion coefficient
   - 3.3 Overview of basic nanoelectronics, quantum and classical regimes of electron transport, Boltzman transport equation, Landauer's Transport equation, quantum electron transport, coherent tunnelling and sequential tunnelling.
   - 3.3 Molecular Electronic Components

   Molecular switches and complex molecular devices, polyphenylene based molecular wires and rectifying diode switches, Quantum Dots & Quantum wires, Single Electron Devices. Negative differential resistance (NDR), Coulomb blockade.

   3.4 Spintronics: Introduction, Overview, Spin filters, Spintronic devices and applications.

Outcomes:

Students attending the course are expected to

- Understand the differences in working principles of nanoscale and macroscale machines.
- Understand functions of simple molecular machine components synthesized artificially, like rotors, turnstiles, motors, switches, rotaxanes, catenanes etc.

• Understand concept of molecular electronics and nanoscale electronic transport.
• Identify features required for molecular electronic functions like switching, sensing, diodes, etc. and understand their working principles.
• Learn to search and read relevant research papers and learn presentation of scientific literature

AIS 5219: Advanced Simulations & Data Science

Content:

Programming Language:

Basic knowledge of C or Fortran 90 – Data statements, Logical and Arithmetic expressions, Operators, I-O statements, Implementation of Loops, Control Statements, Functions and Subroutines, Array manipulation, Processing Strings and Characters, Format Specifications, File processing, Derived types, Pointers and Structure Data Type. Familiarization with Linux based operating system, development of simple C or Fortran programs, compilation and execution.

Numerical Method:

Root finding of equations having numerical coefficients using Successive Bi-section and Newton Raphson method, Basic ideas of Interpolation – Newton's forward and backward interpolation, Lagrange method for unequal intervals, Numerical integration of a definite integral using Trapezoidal and Simpson's one-third rule, Statistical Description of Data, Fast Fourier Transform, Fourier and Spectral Applications, Numerical solution for a set of coupled ordinary differential equation –, Initial Value Problem: Runge Kutta Method, (ii) Boundary Value Problem: Relaxation Technique, Shooting Method, Partial Differential Equations (PDE): (i) Elliptic PDE – Static Boundary Value Problems, (ii) Parabolic PDE – Time Evolution or Dynamic Initial Value Problems, (iii) Hyperbolic PDE – Wave Propagation Problem

AIS 5220 / PHS 5203: Advanced Condensed Matter Physics

Review of one-electron band theory, Electron-electron interaction, Hartree and Hartree-Fock Approximation, exchange and correlation effect, DFT, Fermi liquid theory, Elementary excitations, Quasi-particles, Dielectric function of electron systems, Screening, Plasma oscillation, The Hubbard model, Metal-insulation transition, optical properties of metals and insulators, Excitons, Review of Harmonic theory of Lattice vibrations.

Electron-phonon interactions, Phonons in metals, mass renormalization, Effective interactions between electrons, Polarons, Transport phenomena, Boltzmann equation, Electrical and Thermal conductivities, Thermoelectric effects.

Review of Magnetism, Spin waves. Superconductivity-phenomenology, Copper instability, BCS theory.

AIS 5206: Project with seminar

SEC 5200: Seminar / Colloquium

Objective

1. Students will get the confidence to present in front of the audience
2. Students will learn communication skills to present the seminar
3. Students will acquire the time management skills

Outcome

1. Students demonstrate their confidence to present in front of the audience

2. Students got the presentation and communication skills. 3. Students got the idea about how to manage their time efficiently during the seminar.

Courses starting with “CHS” are offered by School of Chemical Sciences
Courses starting with “SBS” are offered by School of Biological Sciences
Courses starting with “PH” are offered by School of Physical Sciences
Courses starting with “MS” are offered by School of Material Sciences
For these course contents please visit the website of the respective schools.
“L-T-P” stands for “lecture-tutorial-practical”.