

## **Part—A**

### **Syllabus of Research Methodology -- Science (Physics, Chemistry and Biotechnology)**

- **Introduction:** Motivation and objectives of Research –Limitations in Research –Qualities of a Good Research Worker –Criteria of Good Research –Limitations of Research
- **Types of Research and Approaches:** Fundamental, Pure or Theoretical Research –Applied Research –Descriptive Research –Evaluation Research –Experimental Research –Survey Research –Qualitative Research –Quantitative Research –Historical Research
- **Research formulation:** Defining and formulating the research problem, selecting the problem,necessity of defining the problem.
- **Literature Review:** Purpose of Review of Literature –Literature Search Procedure –Sources of Literature –Importance of Review of Literature-Identifying gap areas from literature review and research databases, development of working hypothesis.
- **Thesis writing:** Structure and components of scientific reports-types of report - technical reports and thesis -Thesis writing –design and preparation of thesis (chapter plan and language of typical reports, Illustrations and tables, bibliography, referencing and footnotes).
- **Ethical issues in research:** Code of Ethics in Research –Ethics and Research Process – Importance of Ethics in Research

### **Reference Books:**

- 1.KOTHARI (CR), Research Methodology: Methods and Techniques (2nd edition), New Age International, 2009.
- 2.TROCHIM (WT), Research Methods: The Concise Knowledge Base, Atomic Dog Publisher, 2004. (ISBN: 1592601464).
3. GOODE (WJ) and HATT (PK), Methods in social research. McGraw-Hill,(1982) New York.

## **Part—B: Syllabus for Science Subjects.**

### **Part – B1 Syllabus for Physics Subject**

#### **I. Mathematical Methods of Physics**

Dimensional analysis. Vector algebra and vector calculus. Linear algebra, matrices, Cayley-Hamilton Theorem. Eigenvalues and eigenvectors. Linear ordinary differential equations of first

& second order, Special functions (Hermite, Bessel, Laguerre and Legendre functions). Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues and evaluation of integrals. Elementary probability theory, random variables, binomial, Poisson and normal distributions. Central limit theorem.

## II. Classical Mechanics

Newton's laws. Dynamical systems, Phase space dynamics, stability analysis. Central force motions. Two body Collisions - scattering in laboratory and Centre of mass frames. Rigid body dynamics-moment of inertia tensor. Non-inertial frames and pseudoforces. Variational principle. Generalized coordinates. Lagrangian and Hamiltonian formalism and equations of motion. Conservation laws and cyclic coordinates. Periodic motion: small oscillations, normal modes. Special theory of relativity-Lorentz transformations, relativistic kinematics and mass-energy equivalence.

## III. Electromagnetic Theory

Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems. Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces. Scalar and vector potentials, gauge invariance. Electromagnetic waves in free space. Dielectrics and conductors. Reflection and refraction, polarization, Fresnel's law, interference, coherence, and diffraction. Dynamics of charged particles in static and uniform electromagnetic fields.

## IV. Quantum Mechanics

Wave-particle duality. Schrödinger equation (time-dependent and time-independent). Eigenvalue problems (particle in a box, harmonic oscillator, etc.). Tunneling through a barrier. Wave-function in coordinate and momentum representations. Commutators and Heisenberg uncertainty principle. Dirac notation for state vectors. Motion in a central potential: orbital angular momentum, angular momentum algebra, spin, addition of angular momenta; Hydrogen atom. Stern-Gerlach experiment. Time-independent perturbation theory and applications. Variational method. Time dependent perturbation theory and Fermi's golden rule, selection rules. Identical particles, Pauli exclusion principle, spin-statistics connection.

## V. Thermodynamic and Statistical Physics

Laws of thermodynamics and their consequences. Thermodynamic potentials, Maxwell relations, chemical potential, phase equilibria. Phase space, micro- and macro-states. Micro-canonical, canonical and grand-canonical ensembles and partition functions. Free energy and its connection with thermodynamic quantities. Classical and quantum statistics. Ideal Bose and Fermi gases. Principle of detailed balance. Blackbody radiation and Planck's distribution law.

## VI. Electronics and Experimental Methods

Semiconductor devices (diodes, junctions, transistors, field effect devices, homo- and hetero-junction devices), device structure, device characteristics, frequency dependence and applications. Opto-electronic devices (solar cells, photo-detectors, LEDs). Operational amplifiers and their applications. Digital techniques and applications (registers, counters, comparators and similar circuits). A/D and D/A converters. Microprocessor and microcontroller basics. Data

interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least squares fitting,

## **ADVANCED TOPICS:**

### **I. Mathematical Methods of Physics**

Green's function. Partial differential equations (Laplace, wave and heat equations in two and three dimensions). Elements of computational techniques: root of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule, Solution of first order differential equation using Runge-Kutta method. Finite difference methods. Tensors. Introductory group theory: SU(2), O(3).

### **II. Classical Mechanics**

Dynamical systems, Phase space dynamics, stability analysis. Poisson brackets and canonical transformations. Symmetry, invariance and Noether's theorem. Hamilton-Jacobi theory.

### **III. Electromagnetic Theory**

Dispersion relations in plasma. Lorentz invariance of Maxwell's equation. Transmission lines and wave guides. Radiation- from moving charges and dipoles and retarded potentials.

### **IV. Quantum Mechanics**

Spin-orbit coupling, fine structure. WKB approximation. Elementary theory of scattering: phase shifts, partial waves, Born approximation. Relativistic quantum mechanics: Klein-Gordon and Dirac equations. Semi-classical theory of radiation.

### **V. Thermodynamic and Statistical Physics**

First- and second-order phase transitions. Diamagnetism, paramagnetism, and ferromagnetism. Ising model. Bose-Einstein condensation. Diffusion equation. Random walk and Brownian motion. Introduction to nonequilibrium processes.

### **VI. Electronics and Experimental Methods**

Linear and nonlinear curve fitting, chi-square test. Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). Measurement and control. Signal conditioning and recovery. Impedance matching, amplification (Op-amp based, instrumentation amp, feedback), filtering

and noise reduction, shielding and grounding. Fourier transforms, lock-in detector, box-car integrator, modulation techniques. High frequency devices (including generators and detectors).

### **VII. Atomic & Molecular Physics**

Quantum states of an electron in an atom. Electron spin. Spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectrum lines, LS & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Electron spin resonance. Nuclear magnetic resonance, chemical shift. Frank-Condon principle.

Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Lasers: spontaneous and stimulated emission, Einstein A & B coefficients. Optical pumping, population inversion, rate equation. Modes of resonators and coherence length.

### **VIII. Condensed Matter Physics**

Bravais lattices. Reciprocal lattice. Diffraction and the structure factor. Bonding of solids. Elastic properties, phonons, lattice specific heat. Free electron theory and electronic specific heat. Response and relaxation phenomena. Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Electron motion in a periodic potential, band theory of solids: metals, insulators and semiconductors. Superconductivity: type-I and type-II superconductors. Josephson junctions. Superfluidity. Defects and dislocations. Ordered phases of matter: translational and orientational order, kinds of liquid crystalline order. Quasi crystals.

### **IX. Nuclear and Particle Physics**

Basic nuclear properties: size, shape and charge distribution, spin and parity. Binding energy, semi-empirical mass formula, liquid drop model. Nature of the nuclear force, form of nucleon-nucleon potential, charge-independence and charge-symmetry of nuclear forces. Deuteron problem. Evidence of shell structure, single-particle shell model, its validity and limitations. Rotational spectra. Elementary ideas of alpha, beta and gamma decays and their selection rules. Fission and fusion. Nuclear reactions, reaction mechanism, compound nuclei and direct reactions.

Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellmann-Nishijima formula. Quark model, baryons and mesons. C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction. Relativistic kinematics.

## **Part—B2 Syllabus for Chemistry Subject**

### **INORGANIC CHEMISTRY**

Atomic structure, Chemical bonding, Transition & Inner Transition elements and coordination compounds: structure, bonding theories, spectral and magnetic properties, reaction mechanisms, Organometallic compounds: synthesis, bonding and structure, and reactivity. Organometallics in homogeneous catalysis. Bioinorganic chemistry: photosystems, porphyrins, metalloenzymes, oxygen transport, electron- transfer reactions; nitrogen fixation, metal complexes in medicine. Characterization of inorganic compounds by spectroscopic and microscopic techniques.

### **PHYSICAL CHEMISTRY**

Thermodynamics: First, second and third law of thermodynamics, concept of partial molar quantities. Thermodynamic probability and entropy, distribution laws: Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac, concept of partition function: rotational, translational, vibrational and electronic partition functions of diatomic molecule, Gibb's paradox. Chemical kinetics: Empirical

rate laws and temperature dependence; complex reactions; steady state approximation; collision and transition state theories of rate constants; unimolecular reactions; enzyme kinetics; salt effects; catalysis; unimolecular and bimolecular surface reaction. Electrochemistry: Nernst equation, redox systems, electrochemical cells; Debye-Hückel theory; electrolytic conductance, Kohlrausch's law and its applications; conductometric and potentiometric titrations. Quantum mechanics: Postulates; operator algebra; exactly-solvable systems: particle-in-a-box, harmonic oscillator and the hydrogen atom, tunneling. Approximate methods of quantum mechanics: Variational principle; perturbation theory up to second order in energy; applications. Chemical bonding in diatomics; elementary concepts of MO and VB theories; Huckel theory for conjugated  $\pi$ -electron systems. Group theory: symmetry elements; point groups; character tables; selection rules. Molecular spectroscopy: Rotational and vibrational spectra of diatomic molecules; electronic spectra; IR and Raman activities—selection rules; basic principles of NMR. Polymer chemistry: Molar masses; kinetics of polymerization, Controlled polymerization techniques.

## ORGANIC CHEMISTRY

Principles of stereochemistry: Configurational and conformational isomerism in acyclic and cyclic compounds; stereogenicity, stereoselectivity, enantioselectivity, diastereoselectivity and asymmetric induction. Aromaticity: Benzenoid and non-benzenoid compounds – generation and reactions. Common named reactions and rearrangements. Organic transformations and reagents: Functional groups inter conversion including oxidations and reductions; common catalysts and reagents, Chemo, regio and stereoselective transformations. Concepts in organic synthesis: Retrosynthesis, disconnection, synthons, linear and convergent synthesis, umpolung of reactivity and protecting groups. Asymmetric synthesis: Chiral auxiliaries, methods of asymmetric induction, determination of enantiomeric and diastereomeric excess; enantio-discrimination. Pericyclic reactions: electrocyclisation, cycloaddition, sigmatropic rearrangements and other related concerted reactions. Principles and applications of photochemical reactions in organic chemistry. Synthesis and reactivity of common heterocyclic compounds, structure determination of organic compounds by IR, UV-Vis,  $^1\text{H}$  &  $^{13}\text{C}$  NMR and Mass spectroscopic techniques.

## Part—B3 Syllabus for Biotechnology Subject

### UNIT I - CELLULAR ORGANIZATION

#### A) Membrane structure and function

(Structure of model membrane, lipid bilayer and membrane protein diffusion, osmosis, ion channels, active transport, membrane pumps, mechanism of sorting and regulation of intracellular transport, electrical properties of membranes).

**B) Structural organization and function of intracellular organelles** (Cell wall, nucleus, mitochondria, Golgi bodies, lysosomes, endoplasmic reticulum, peroxisomes, plastids, vacuoles, chloroplast, structure & function of cytoskeleton and its role in motility).

**C) Organization of genes and chromosomes** (Operon, unique and repetitive DNA, interrupted genes, gene families, structure of chromatin and chromosomes, heterochromatin, euchromatin, transposons).

**D) Cell division and cell cycle** (Mitosis and meiosis, their regulation, steps in cell cycle, regulation and control of cell cycle).

**E) Microbial Physiology** (Growth yield and characteristics, strategies of cell division, stress response)

## **UNIT II - FUNDAMENTAL PROCESSES**

**A) DNA replication, repair and recombination** (Unit of replication, enzymes involved, replication origin and replication fork, fidelity of replication, extrachromosomal replicons, DNA damage and repair mechanisms, homologous and site-specific recombination).

**B) RNA synthesis and processing** (transcription factors and machinery, formation of initiation complex, transcription activator and repressor, RNA polymerases, capping, elongation, and termination, RNA processing, RNA editing, splicing, and polyadenylation, structure and function of different types of RNA, RNA transport).

**C) Protein synthesis and processing** (Ribosome, formation of initiation complex, initiation factors and their regulation, elongation and elongation factors, termination, genetic code, aminoacylation of tRNA, tRNA-identity, aminoacyl tRNA synthetase, and translational proof-reading, translational inhibitors, Post-translational modification of proteins).

**D) Control of gene expression at transcription and translation level** (regulating the expression of phages, viruses, prokaryotic and eukaryotic genes, role of chromatin in gene expression and gene silencing).

## **UNIT III - Cell communication and cell signaling**

**A) Host parasite interaction** Recognition and entry processes of different pathogens like bacteria, viruses into animal and plant host cells, alteration of host cell behavior by pathogens, virus-induced cell transformation, pathogen-induced diseases in animals and plants, cell-cell fusion in both normal and abnormal cells.

**B) Cell signaling** Hormones and their receptors, cell surface receptor, signaling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component systems, light signaling in plants, bacterial chemotaxis and quorum sensing.

**C) Cellular communication** Regulation of hematopoiesis, general principles of cell communication, cell adhesion and roles of different adhesion molecules, gap junctions, extracellular matrix, integrins, neurotransmission and its regulation.

**D) Cancer** Genetic rearrangements in progenitor cells, oncogenes, tumor suppressor genes, cancer and the cell cycle, virus-induced cancer, metastasis, interaction of cancer cells with normal cells, apoptosis, therapeutic interventions of uncontrolled cell growth.

**E) Innate and adaptive immune system** Cells and molecules involved in innate and adaptive immunity, antigens, antigenicity and immunogenicity. B and T cell epitopes, structure and function of antibody molecules. generation of antibody diversity, monoclonal antibodies, antibody engineering, antigen-antibody interactions, MHC molecules, antigen processing and presentation, activation and differentiation of B and T cells, B and T cell receptors, humoral and cellmediated immune responses, primary and secondary immune modulation, the complement system, Toll-like receptors, cell-mediated effector functions,= inflammation, hypersensitivity and autoimmunity, immune response during bacterial (tuberculosis), parasitic (malaria) and viral (HIV) infections, congenital and acquired immunodeficiencies, vaccines.

#### **UNIT IV - INHERITANCE BIOLOGY**

**A) Mendelian principles** : Dominance, segregation, independent assortment.

**B) Concept of gene** : Allele, multiple alleles, pseudoallele, complementation tests

**C) Extensions of Mendelian principles** : Codominance, incomplete dominance, gene interactions, pleiotropy, genomic imprinting, penetrance and expressivity, phenocopy, linkage and crossing over, sex linkage, sex limited and sex influenced characters.

**D) Gene mapping methods** : Linkage maps, tetrad analysis, mapping with molecular markers, mapping by using somatic cell hybrids, development of mapping population in plants.

**E) Extra chromosomal inheritance** : Inheritance of Mitochondrial and chloroplast genes, maternal inheritance.

**F) Microbial genetics** : Methods of genetic transfers – transformation, conjugation, transduction and sex-duction, mapping genes by interrupted mating, fine structure analysis of genes.

**G) Human genetics** : Pedigree analysis, lod score for linkage testing, karyotypes, genetic disorders.

**H) Quantitative genetics** : Polygenic inheritance, heritability and its measurements, QTL mapping.

**I) Mutation** : Types, causes and detection, mutant types – lethal, conditional, biochemical, loss of function, gain of function, germinal verses somatic mutants, insertional mutagenesis.

**J) Structural and numerical alterations of chromosomes** : Deletion, duplication, inversion, translocation, ploidy and their genetic implications.

**K) Recombination** : Homologous and non-homologous recombination including transposition.

## **UNIT V - METHODS IN BIOLOGY**

**A. Molecular Biology and Recombinant DNA methods:** Isolation and purification of RNA , DNA (genomic and plasmid) and proteins, different separation methods. Analysis of RNA, DNA and proteins by one and two dimensional gel electrophoresis, Isoelectric focusing gels. Molecular cloning of DNA or RNA fragments in bacterial and eukaryotic systems. Expression of recombinant proteins using bacterial, animal and plant vectors. Isolation of specific nucleic acid sequences. Generation of genomic and cDNA libraries in plasmid, phage, cosmid, BAC and YAC vectors. In vitro mutagenesis and deletion techniques, gene knock out in bacterial and eukaryotic organisms. Protein sequencing methods, detection of post translation modification of proteins. DNA sequencing methods, strategies for genome sequencing. Methods for analysis of gene expression at RNA and protein level, large scale expression, such as micro array based techniques. Isolation, separation and analysis of carbohydrate and lipid molecules RFLP, RAPD and AFLP techniques

**B. Histochemical and Immunotechniques :** Antibody generation, Detection of molecules using ELISA, RIA, western blot, immunoprecipitation, fluocytometry and immunofluorescence microscopy, detection of molecules in living cells, in situ localization by techniques such as FISH and GISH.

**C. Biophysical Method:** Molecular analysis using UV/visible, fluorescence, circular dichroism, NMR and ESR spectroscopy Molecular structure determination using X-ray diffraction and NMR, Molecular analysis using light scattering, different types of mass spectrometry and surface plasma resonance methods.

**D. Radiolabeling techniques:** Detection and measurement of different types of radioisotopes normally used in biology, incorporation of radioisotopes in biological tissues and cells, molecular imaging of radioactive material, safety guidelines.

**E. Microscopic techniques:** Visualization of cells and subcellular components by light microscopy, resolving powers of different microscopes, microscopy of living cells, scanning and transmission microscopes, different fixation and staining techniques for EM, freeze-etch and freeze fracture methods for EM, image processing methods in microscopy.

**F. Electrophysiological methods:** Single neuron recording, patch-clamp recording, ECG, Brain activity recording, lesion and stimulation of brain, pharmacological testing, PET, MRI, fMRI, CAT.