Syllabus for Ph.D. Entrance Test under Sciences

(Life Sciences/Biotechnology, Physics, Chemistry and Mathematics)

PAPER 1 (Common for all Sciences)

1. Logical Reasoning
2. Numerical Ability
3. General Aptitude (Research Aptitude)

Life Sciences/Biotechnology

PAPER 2

1. **DIVERSITY OF LIFE FORMS & EVOLUTION**

- Principles & methods of taxonomy: Concepts of species and hierarchical taxa, biological nomenclature, classical & quantititative methods of taxonomy of plants, animals and microorganisms.
- Levels of structural organization: Unicellular, colonial and multicellular forms. Levels of organization of tissues, organs & systems. Comparative anatomy, adaptive radiation, adaptive modifications.
- Outline classification of plants, animals & microorganisms: Important criteria used for classification in each taxon. Classification of plants, animals and microorganisms. Evolutionary relationships among taxa.
- Natural history of Indian subcontinent: Major habitat types of the subcontinent, geographic origins and migrations of species. Common Indian mammals, birds. Seasonality and phenology of the subcontinent.
- Organisms of health, agricultural importance: Common parasites and pathogens of humans, domestic animals and crops. Organisms of conservation concern: Rare, endangered species. Conservation strategies
- Evolutionary theories -Lamarck; Darwin–concepts of variation, adaptation, struggle, fitness and natural selection; Mendelism; Spontaneity of mutations; the evolutionary synthesis.
- Origin of cells and unicellular evolution: Origin of basic biological molecules; Abiotic synthesis of organic monomers and polymers; Concept of Oparin and Haldane; Experiement of Miller (1953); The first cell; Evolution of prokaryotes; Origin of eukaryotic cells; Evolution of unicellular eukaryotes; Anaerobic metabolism, photosynthesis and aerobic metabolism.
- Paleontology and Evolutionary History: The evolutionary time scale; Eras, periods and epoch; Major events in the evolutionary time scale; Origins of unicellular and multi cellular organisms; Major groups of plants and animals; Stages in primate evolution including Homo. Molecular Evolution: Concepts of neutral evolution, molecular divergence and molecular clocks; Molecular tools in phylogeny, classification and identification; Protein and nucleotide sequence analysis; Origin of new genes and proteins; Gene duplication and divergence
- Population genetics – Populations, Gene pool, Gene frequency; Hardy-Weinberg Law; concepts and rate of change in gene frequency through natural selection, migration and random genetic drift; Adaptive radiation; Isolating mechanisms; Speciation; Allopatricity and Sympatricity; Convergent evolution; Sexual selection; Co-evolution

2. ECOLOGY

- Environment: Physical environment; biotic environment; biotic and abiotic interactions.
- Habitat and Niche: Concept of habitat and niche; niche width and overlap; fundamental and realized niche; resource partitioning; character displacement.
- Population Ecology: Characteristics of a population; population growth curves; population regulation; life history strategies (r and K selection); concept of metapopulation – demes and dispersal, interdemic extinctions, age structured populations.
- Species Interactions: Types of interactions, interspecific competition, herbivory, carnivory, pollination, symbiosis.
- Community Ecology: Nature of communities; community structure and attributes; levels of species diversity and its measurement; edges and ecotones.
- Ecological Succession: Types; mechanisms; changes involved in succession; concept of climax. Ecosystem Ecology: Ecosystem structure; ecosystem function; energy flow and mineral cycling (C,N,P); primary production and decomposition; structure and function of some Indian ecosystems: terrestrial (forest, grassland) and aquatic (fresh water, marine, eustarine). Biogeography: Major terrestrial biomes; theory of island biogeography; biogeographical zones of India.
- Applied Ecology: Environmental pollution; global environmental change; biodiversity: status, monitoring and documentation; major drivers of biodiversity change; biodiversity management approaches.
- Conservation Biology: Principles of conservation, major approaches to management, Indian case studies on conservation/management strategy (Project Tiger, Biosphere reserves).

3. CELLS AND MOLECULES OF LIFE

- Structure of atoms, molecules and chemical bonds.
- Composition, structure and function of biomolecules (carbohydrates, lipids, proteins, nucleic acids and vitamins).
- Stablizing interactions (Van der Waals, electrostatic, hydrogen bonding, hydrophobic interaction, etc.).
- Principles of biophysical chemistry (pH, buffer, reaction kinetics, thermodynamics, colligative properties).
- Bioenergetics, glycolysis, oxidative phosphorylation, coupled reaction, group transfer, biological energy transducers.
- Principles of catalysis, enzymes and enzyme kinetics, enzyme regulation, mechanism of enzyme catalysis, isozymes
- Conformation of proteins (Ramachandran plot, secondary structure, domains, motif and folds).
- Conformation of nucleic acids (A, B, Z helix, t-RNA, micro-RNA).
- Stability of proteins and nucleic acids.
- Metabolism of carbohydrates, lipids, amino acids nucleotides and vitamins.
- Structural organization and function of intracellular organelles (Cell wall, cell membrane, nucleus, ribosomes, Golgi apparatus, Endoplasmic reticulum, Lysosomes)
- Cells of immunity- Cells and molecules involved in innate and adaptive immunity, antigens, antigenicity and immunogenicity. B and T cell epitopes, structure and function of antibody molecules.

4. CELLULAR ORGANISATION AND CELL COMMUNICATION

- 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).
- Organization of genes and chromosomes (Operon, unique and repetitive DNA, interrupted genes, gene families, structure of chromatin and chromosomes, heterochromatin, euchromatin, transposons).
- Cell division and cell cycle (Mitosis and meiosis, their regulation, steps in cell cycle, regulation and control of cell cycle).
- Microbial Physiology (Growth yield and characteristics, strategies of cell division, stress response)
- Host parasite interaction (Recognition and entry processes of different pathogens like bacteria, viruses into animal and plant host cells, alteration of host cell behavior by pathogens, virus-induced cell transformation, pathogen-induced diseases in animals and plants, cell-cell fusion in both normal and abnormal cells).
- Cell signaling - Hormones and their receptors, cell surface receptor, signaling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component systems, light signaling in plants, bacterial chemotaxis and quorum sensing.
- 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.
- Immunity: Innate and adaptive immune system, MHC molecules, cytokines, activation and differentiation of B and T cells, B and T cell receptors, humoral and cell-mediated 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.

5. GENETIC EXPRESSION AND REARRANGEMENT

- 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).
- 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).
- 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).
- 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, gene imprinting).
- Mutation : Types, causes and detection, mutant types – lethal, conditional, biochemical, loss of function, gain of function, germinal verses somatic mutants, insertional mutagenesis. Structural and numerical alterations of chromosomes: Deletion, duplication, inversion, translocation, ploidy and their genetic implications.
- Recombination : Homologous and non-homologous recombination including transposition

- Gene rearrangements : 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. Generation of antibody diversity, monoclonal antibodies, antibody engineering, antigen-antibody interactions, antigen processing and presentation

6. **DEVELOPMENTAL BIOLOGY**

- Basic concepts of development : Potency, commitment, specification, induction, competence, determination and differentiation; morphogenetic gradients; cell fate and cell lineages; stem cells; genomic equivalence and the cytoplasmic determinants; imprinting; mutants and transgenics in analysis of development
- Gametogenesis, fertilization and early development: Production of gametes, cell surface molecules in sperm-egg recognition in animals; embryo sac development and double fertilization in plants; zygote formation, cleavage, blastula formation, embryonic fields, gastrulation and formation of germ layers in animals; embryogenesis, establishment of symmetry in plants; seed formation and germination.
- Morphogenesis and organogenesis in animals : Cell aggregation and differentiation in Dictyostelium; axes and pattern formation in Drosophila, amphibia and chick; organogenesis – vulva formation in Caenorhabditis elegans, eye lens induction, limb development and regeneration in vertebrates; differentiation of neurons, post embryonic development- larval formation, metamorphosis; environmental regulation of normal development; sex determination.
- Morphogenesis and organogenesis in plants: Organization of shoot and root apical meristem; shoot and root development; leaf development and phyllotaxy; transition to flowering, floral meristems and floral development in Arabidopsis and Antirrhinum
- Programmed cell death, aging and senescence

7. **SYSTEM PHYSIOLOGY - PLANT & ANIMALS**

Plant System

- Photosynthesis - Light harvesting complexes; mechanisms of electron transport; photoprotective mechanisms; CO_2 fixation-C3, C4 and CAM pathways.
- Respiration and photorespiration – Citric acid cycle; plant mitochondrial electron transport and ATP synthesis; alternate oxidase; photorespiratory pathway. Nitrogen metabolism - Nitrate and ammonium assimilation; amino acid biosynthesis.
- Plant hormones – Biosynthesis, storage, breakdown and transport; physiological effects and mechanisms of action.
- Sensory photobiology - Structure, function and mechanisms of action of phytochromes, cryptochromes and phototropins; stomatal movement; photoperiodism and biological clocks.
- Solute transport and photoassimilate translocation – uptake, transport and translocation of water, ions, solutes and macromolecules from soil, through cells, across membranes, through xylem and phloem; transpiration; mechanisms of loading and unloading of photoassimilates.
- Secondary metabolites - Biosynthesis of terpenes, phenols and nitrogenous compounds and their roles. Stress physiology – Responses of plants to biotic (pathogen and insects) and abiotic (water, temperature and salt) stresses.

Animal System

- Blood and circulation - Blood corpuscles, haemopoiesis and formed elements, plasma function, blood volume, blood volume regulation, blood groups**,** haemoglobin, immunity

haemostasis. Cardiovascular System: Comparative anatomy of heart structure, myogenic heart, specialized tissue, ECG – its principle and significance, cardiac cycle, heart as a pump, blood pressure, neural and chemical regulation of all above

- Respiratory system - Comparison of respiration in different species, anatomical considerations, transport of gases, exchange of gases, waste elimination, neural and chemical regulation of respiration.
- Nervous system - Neurons, action potential, gross neuroanatomy of the brain and spinal cord, central and peripheral nervous system, neural control of muscle tone and posture.ense organs - Vision, hearing and tactile response.
- Excretory system - Comparative physiology of excretion, kidney, urine formation, urine concentration, waste elimination, micturition, regulation of water balance, blood volume, blood pressure, electrolyte balance, acid-base balance.
- Thermoregulation - Comfort zone, body temperature – physical, chemical, neural regulation, acclimatization. Stress and adaptation
- Digestive system - Digestion, absorption, energy balance, BMR.
- Endocrinology and reproduction - Endocrine glands, basic mechanism of hormone action, hormones and diseases; reproductive processes, gametogenesis, ovulation,neuroendocrine regulation

8. **INHERITANCE BIOLOGY**

- Mendelian principles : Dominance, segregation, independent assortment.
- Concept of gene : Allele, multiple alleles, pseudoallele, complementation tests
- 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.
- Gene mapping methods: Linkage maps, tetrad analysis, mapping with molecular markers, mapping by using somatic cell hybrids, development of mapping population in plants.
- Extra chromosomal inheritance: Inheritance of Mitochondrial and chloroplast genes, maternal inheritance.
- Microbial genetics : Methods of genetic transfers – transformation, conjugation, transduction and sexduction, mapping genes by interrupted mating, fine structure analysis of genes.
- Human genetics : Pedigree analysis, lod score for linkage testing, karyotypes, genetic disorders.
- Quantitative genetics: Polygenic inheritance, heritability and its measurements, QTL mapping.

9. **APPLIED BIOLOGY**

- Microbial fermentation and production of small and macro molecules.
- Application of immunological principles, vaccines, diagnostics. Tissue and cell culture methods for plants and animals.
- Transgenic animals and plants, molecular approaches to diagnosis and strain identification. Terminator gene technology
- Bioinformatics: Genome, Transcriptome, Proteome. Gene Databanks. Human Genome project, Variome projects, Micro biome projects. Genomics and proteomics and its application to health and agriculture. Primer designing, Kit development, Gene therapy.
- Bioresource and uses of biodiversity.
- Breeding in plants and animals, including marker – assisted selection
- Bioremediation and phytoremediation
- Biosensors
- Probiotics: Health and agriculture

10. **METHODS IN BIOLOGY**

- 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
- 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.
- 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.
- Statisitcal Methods: Measures of central tendency and dispersal; probability distributions (Binomial, Poisson and normal); Sampling distribution; Difference between parametric and non-parametric statistics; Confidence Interval; Errors; Levels of significance; Regression and Correlation; t-test; Analysis of variance; X2 test;; Basic introduction to Muetrovariate statistics, etc.
- 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.
- Microscopic techniques: Visualization of cells and sub-cellular components by light microscopy, resolving powers of different microscopes, microscopy of living cells, scanning and transmission microscopes, different fixation and staining techniques for EM, freeze-etch and freeze- fracture methods for EM, image processing methods in microscopy.
- Electrophysiological methods: Single neuron recording, patch-clamp recording, ECG, Brain activity recording, lesion and stimulation of brain, pharmacological testing, PET, MRI, fMRI, CAT.
- Methods in field biology: Methods of estimating population density of animals and plants, ranging patterns through direct, indirect and remote observations, sampling methods in the study of behavior, habitat characterization: ground and remote sensing methods.

Chemistry

PAPER 2

Physical Chemistry

1**. Some basic Concept of Chemistry**: Matter and its nature, Daltons atomic theory; concept of atom, molecule, element and compound; Physical quantities and their measurements in Chemistry, precision and accuracy, significant figures, S.I. units, dimensional analysis; Laws of chemical combination; Atomic and molecular masses, mole concept, molar mass, percentage composition, empirical and molecular formulae,; Chemical equations and stoichiometry.

2. **States of Matter, Chemical Bonding and Molecular structure**: Classification of matter: Gaseous state: Liquid State and Solid State, Ionic bonding, Covalent bonding, Quantum mechanical approach to covalent bonding; Molecular orbital Theory.

3. **Chemical Thermodynamics**: Fundamentals, First Law of thermodynamics: Concept of work, heat, internal energy and enthalpy, heat capacity, molar heat capacity; Hess's Law of constant heat summation; Enthalpies of bond dissociation, combustion, formation, atomization, sublimation, phase transition, hydration, ionization, and solution, Second Law of thermodynamics: Spontaneous processes, ΔS, ΔG, ΔGo, and equilibrium constant.

4. **Solutions:** Molarity, Molality, mole fraction, percentage, vapour pressure of solutions, Raoult's Law-Ideal and non-ideal solutions, vapour pressure; Colligative properties of dilute solutions, relative lowering of vapour pressure, depression of freezing point, elevation of boiling point and osmotic pressure; Determination of molecular mass using colligative properties; Abnormal values of molar mass; vant's Hoff Factor and its significance.

5. **Equilibrium:** Concept of equilibrium and dynamic equilibrium, Equilibria involving physical process, Equilibria involving chemical processes, Ionic Equilibrium: Weak and strong electrolytes, ionization of electrolytes, Acid Base concepts(Arrhenius, Bronsted-Lowry and Lewis), Acid – Base equilibria, Ionization constants, ionization of water, pH scale, common ion effect, hydrolysis of salts and pH of their solutions, solubility of sparingly soluble salts, solubility products and buffer solutions.

6. **Redox reactions and Electrochemistry:** Concepts of oxidation and reduction, redox reactions, oxidation number, rules for assigning oxidation number, balancing of redox reactions, Electrolytic and metallic conduction, conductance, molar conductivities and their variation with concentration, Kohlrausch's law and its applications. Electrochemical cells, Electrodes, electrode potentials, Standard electrode potential, Half-cell and cell reactions, emf of a galvanic cell and its measurements, Nernst equation, relationship between EMF and Gibb's energy change; Dry cell and Lead acid batteries, Fuel cells

7. **Chemical Kinetics**: rates of a chemical reaction, factors affecting the rate of reactions; concentration, temperature, pressure and catalyst, elementary and complex reactions, order and molecularity of reactions, rate law, rate constant and its units, Zero and first order reactions, their characteristics, Half- life, effect of temperature on rate of reactions- Arrhenius theory, activation energy and its calculation, collision theory of bimolecular gaseous reactions.

Inorganic Chemistry

8. **Periodic table and Periodicity in properties:** Modern periodic law and s, p, d and f block elements, periodic trends in properties of elements, atomic and ionic radii, ionization enthalpy, electron gain enthalpy, valence, oxidation states and chemical reactivity.

9. **General principles and process of Isolation of metals:** Mineral, ore, Metallurgy, General principles of metallurgy, Refining of Al, Cu, Zn and Fe.

10**. s-block Elements**: General introduction, electronic configuration, and general trends in physical and chemical properties of elements, anomalous properties if the first element of each group, diagonal relationships, Preparation and properties of sodium carbonate, sodium hydroxide, Sodium bicarbonate, Biological significance of Na, K, Mg and Ca.

11. p-Block elements: Electronic configuration, general trends in physical properties and chemical properties across the periods and down the groups; unique behavior of first element in each group, Group wise study of the p-block elements (Group 13 to Group 18 elements)

12. d- and f- Block elements: Transitions elements: Introduction, electronic configuration, characteristics, general trends in properties of first row transition elements, Preparation, properties and uses of K2Cr2O7 and KMnO4. Lanthanides and Actinides: Electronic configuration and oxidations states.

13. Co-ordination compounds: Introduction, Werner's theory, ligands, co-ordination number, dentacity, chelate complexes, IUPAC names, isomerism, Bonding- valence bond theory, crystal field theory, important coordination compounds in biological systems.

Organic Chemistry

14. Some basic principles of organic Chemistry: Hybridization, Classification of organic compounds based on Functional Groups, Homologous series, Isomerism-structural and stereoisomerism, Nomenclature (Trivial and IUPAC), Free radicals, carbocation, carboanion and their stability, electrophiles and nucleophiles, Inductive effect, electromeric effect, resonance, hyperconjugation, Types of reactions- Substitution, addition, elimination and rearrangement.

15. Hydrocarbons: Alkanes, Alkenes and Alkynes, Aromatic hydrocarbons- Nomenclature, general methods of preparation and chemical reactions, Uses.

16. Halogen derivatives of Alkanes: General methods of preparation, properties and reactions, nature of C-X bond; mechanism of substitution reactions, Uses of chloroform, iodoform, freons and DDT.

17. Compounds containing Oxygen: Alcohols, phenols and ethers, Aldehydes and Ketones: General methods of preparation, properties, reactions and uses.

18. Compounds containing Nitrogen: Amines, Nitro compounds- General methods of preparation, properties, reactions and uses.

19. Polymers: Introduction, classification of polymers, addition and condensation polymerization, Copolymerization, Natural and synthetic rubber, Vulcanization, some important polymer synthesis and uses- polyethene, nylon, polyester and bakelite.

20. Biomolecules: carbohydrates, Proteins, Vitamins and Nucleic acids: Introduction and importance of biomolecules.

Physics

1. **Mathematical Physics:**

   Vector algebra, Vector calculus, Linear algebra, matrices, linear differential equations, elements of complex analysis: Cauchy-Riemann conditions, Cauchy's theorems, singularities, residue theorem and applications; Fourier and Laplace transforms, elementary ideas about tensors.

2. **Classical Mechanics:**

   Newton's laws, D'Alembert's principle, cyclic coordinates, variational principle, Lagrange's equation of motion, central force and scattering problems, rigid body motion; small oscillations, Hamilton's formalisms; Poisson bracket; special theory of relativity: Lorentz transformations, relativistic kinematics, mass-energy equivalence.

3. Electromagnetic Theory

   Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, 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 fields and potentials, gauge invariance. Electromagnetic waves in free space. Dielectrics and conductors. Reflection and refraction, polarization, interference, coherence, and diffraction.

4. Quantum Mechanics

   Wave-particle duality, de-Broglie's hypothesis and its experiential verification, Postulates of quantum mechanics; uncertainty principle; phase velocity and group velocity of matter waves; Schrodinger time dependent and time independent wave equation; potential problems in one-, two- and three-dimensional, particle in infinite potential well (rigid wall), transmission through one dimensional potential barriers, harmonic oscillator, hydrogen atom; linear vectors and operators in Hilbert space; angular momentum and spin; addition of angular momenta; time independent perturbation theory; elementary scattering theory.

5. Thermodynamics and Statistical Physics

   Laws of thermodynamics; Maxwell's fundamentals thermodynamic relations macrostates and microstates; phase space; ensembles; partition function, Free energy and its connection with thermodynamic quantities, calculation of thermodynamic quantities; classical and quantum statistics; degenerate Fermi gas; Planck's radiation formula, black body radiation and Planck's distribution law; Bose-Einstein condensation; first and second order phase transitions, phase equilibria, critical point.

6. Atomic and Molecular Physics

   Quantum states of an electron in an atom, Electron spin, Spectrum of helium and alkali atom. Energy levels of hydrogen atom, Zeeman and Stark effects; electric dipole transitions and selection rules; rotational and vibrational spectra of diatomic molecules; electronic transition in diatomic molecules, Franck-Condon principle; Raman effect; NMR, ESR, X-ray spectra; He-Ne and NdYaG LASERs: Einstein coefficients, Optical pumping, population inversion, two and three level systems

7. **Solid State Physics & Electronics**

   Elements of crystallography; diffraction methods for structure determination; bonding in solids; lattice vibrations and thermal properties of solids; free electron theory; band theory of solids: Fermi level, nearly free electron and tight binding models; metals, semiconductors and insulators; conductivity, mobility and effective mass; optical, Hall effect, dielectric and magnetic properties of solids; elements of superconductivity: Type-I and Type II superconductors, Meissner effect, London equation, Liquid Crystals . Semiconductor devices: diodes, Bipolar Junction Transistors, Field Effect Transistors; operational amplifiers: negative feedback circuits, active filters and oscillators; regulated power supplies; basic digital logic circuits, sequential circuits, flip-flops, counters, registers, A/D and D/A conversion.

8. **Nuclear and Particle Physics**

   Basic nuclear properties: size, shape and charge distribution, spin and parity, nuclear binding energy, Electric and magnetic moments; nuclear models, liquid drop model: semi-empirical mass formula, Fermi gas model of nucleus, nuclear shell model; nuclear force and two nucleon problem; alpha decay, beta-decay, electromagnetic transitions in nuclei; Rutherford scattering, nuclear reactions, conservation laws; fission and fusion; particle accelerators and detectors; elementary particles, photons, baryons, mesons and leptons; quark model.

Mathematics

1. **Analysis:** Elementary set theory, finite, countable and uncountable sets, Real number system as a complete ordered field, Archimedean property, supremum, infimum. limsup, liminf. Bolzano Weierstrass theorem, Heine Borel theorem, Limits , Continuity, uniform continuity, differentiability, mean value theorem, Sequences and series of functions, convergence, uniform convergence, Weierstrass approximation theorem, Riemann sums and Riemann integral, Improper Integrals, Monotonic functions, types of discontinuity, functions of bounded variation, contraction mapping principle, Inverse and Implicit function theorems, Lebesgue measure, measurable functions Lebesgue integral, Functions of several variables, directional derivative, partial derivative, total Derivative, maxima and minima, saddle point, method of Lagrange's multipliers; derivative as a linear transformation, Metric spaces, compactness, connectedness, Normed Linear Spaces, Spaces of Continuous functions, Fatou's lemma, monotone convergence theorem, dominated convergence theorem, Double and Triple integrals and their applications; Line integrals and Surface integrals, Green's theorem, Stokes' theorem, and Gauss divergence theorem.
2. **Complex Analysis**: Algebra of complex numbers, Analytic functions, Harmonic Functions, Cauchy-Riemann equations, Contour integral, line integrals, Cauchy's Theorem and integral formula, Morera's theorem, Liouville's theorem, Maximum modulus principle, Schwarz lemma, Open mapping theorem, Power series, Taylor's and Laurent's series, Classification of zeros & singularities, Radius of Convergence, Residues, Contour integration, Riemann Sphere and Stereographic projection, Conformal mapping, Mobius transformations.
3. **Linear Algebra:** Vector spaces, subspaces, linear dependence, basis, dimension, algebra of linear transformations & their matrix representations, Algebra of matrices, rank and determinant of matrices, rank & nullity, systems of linear equations, Eigenvalues and eigenvectors, Cayley-Hamilton theorem, minimal polynomial, diagonalization, Jordan canonical form, symmetric, skew-symmetric, Hermitian, skew-Hermitian, orthogonal and unitary matrices; Change of basis, canonical forms, diagonal forms, triangular forms, Jordan forms, Finite dimensional inner product spaces, Gram-Schmidt orthonormalization process, definite forms, Inner product spaces, orthonormal basis, Quadratic forms, reduction and classification of quadratic forms.
4. **Algebra:** Permutations, combinations, pigeon-hole principle, inclusion-exclusion principle, derangements, Fundamental theorem of arithmetic, divisibility in Z, congruence, Chinese Remainder Theorem, Euler's Ø- function, primitive roots, Groups, subgroups, normal subgroups, quotient groups, homomorphisms, automorphisms, cyclic groups, permutation groups, Cayley's theorem, class equations, Sylow theorems and their applications, Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain, Polynomial rings and irreducibility criteria, Fields, finite fields, field extensions.
5. **Ordinary Differential Equations (ODEs):** First order ordinary differential equations, existence and uniqueness theorems for initial value problems, singular solutions of first order ODEs, system of first order ODEs, linear ordinary differential equations of higher order with constant coefficients; Second order linear ordinary differential equations with variable coefficients; Cauchy-Euler equation, method of Laplace transforms for solving ordinary differential equations, series solutions (power series, Frobenius method); Legendre and Bessel functions and their orthogonal properties; Systems of linear first order ordinary differential equations, General theory of homogenous and non-homogeneous linear ODEs, variation of parameters, Sturm-Liouville boundary value problem, Green's function
6. **Partial Differential Equations (PDEs):** Linear and quasi-linear first order partial differential equations, Lagrange and Charpit methods for solving first order PDEs, method of characteristics; Second order linear equations in two variables and their classification; General solution of higher order PDEs with constant coefficients, Cauchy, Dirichlet and Neumann problems; Solutions of Laplace and wave equations in two dimensional Cartesian coordinates, interior and exterior Dirichlet problems in polar coordinates; Separation of variables method for Laplace, heat & wave and diffusion equations; Fourier series and Fourier transform and Laplace transform methods of solutions for the equations mentioned above.

7. **Numerical Analysis:** Numerical solutions of algebraic equations and transcendental equations: bisection, secant method, Newton-Raphson method, fixed point iteration, Method of iteration, Rate of convergence, Numerical solution of a system of linear equations: direct methods (Gauss elimination, LU decomposition), iterative methods (Jacobi and Gauss-Seidel); Numerical solution of initial value problems of ODEs: Euler's method, Runge-Kutta methods of order 2, Numerical solutions of ODEs using Picard, Euler, modified Euler and Runge-Kutta methods, Finite differences, Interpolation: error of polynomial interpolation, Lagrange, Newton, Hermite and spline interpolation, Numerical differentiation and Numerical integration: Trapezoidal and Simpson's rules.
8. **Linear Programming:** Linear programming problem and its formulation, convex sets and their properties, graphical method, basic feasible solution, simplex method, two phase methods; infeasible and unbounded LPP's, alternate optima; Dual problem and duality theorems; Balanced and unbalanced transportation problems, Vogel's approximation method for solving transportation problems; Hungarian method for solving assignment problems.
9. **Integral Transform :**Laplace transform; Transform of elementary functions, Transform of Derivatives, Inverse Transform, Convolution Theorem, Applications, Ordinary and Partial differential equations; Fourier transform; sine and cosine transform, Inverse Fourier Transform, Application to ordinary and partial differential equations.
10. **Discrete Mathematics:** Partially ordered sets, Lattices, Cornplete Lattices, Distrbutive lattices, Complements, Boolean Algebra, Boolean Expressions, Application to switching circuits, Elements of Graph Theory, Eulerian and Hamiltonian graphs, planar Graphs, Directed Graphs, Trees, Permutations and Combinations, Pigeonhole principle, principle of Inclusion and Exclusion, Derangements.

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