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UNIT-1: Differential equations

Partial differential equations: Classifications, systems of surfaces and characteristics, examples of hyperbolic, parabola and elliptic equations, method of direct integration, method of separation of variables.

Special differential equations


UNIT-2: Laplace transforms


UNIT-3: Fourier series and integrals


UNIT-4: Group Theory


UNIT-5: Numerical Techniques


REFERENCE BOOKS:
UNIT-1: Newtonian mechanics and
Lagrangian formulation


UNIT-2: Hamiltonian formalism

Relativistic mechanics, Continuum mechanics


a. Relativistic mechanics: Four-dimensional formulation-four-vectors, four-velocity, four-momentum, and four-acceleration. Lorentz co-variant form of equation of motion

b. Continuum mechanics: Basic concepts, Equations of continuity and motion; Simple applications

UNIT-3: Microcanonical, Canonical and Grandcanonical ensembles

Microcanonical distribution function. Two level system in microcanonical ensemble, Gibbs paradox and correct formula for entropy, The canonical distribution function. Contact with thermodynamics - Two level system in canonical ensemble, Partition function and free energy of an ideal gas, Distribution of molecular velocities.

Equipartition and Virial theorems, The grand partition function, Relation between grand canonical and canonical partition functions.


UNIT-4: Bose-Einstein, Fermi-Dirac and Maxwell-Boltzmann Distributions

UNIT-5: Thermodynamics, Microstates and Macrostates


REFERENCE BOOKS:
UNIT-1

a. **Physical basis of quantum mechanics**: Experimental background, inadequacy of classical physics, summary of principal experiments and inferences, Uncertainty and complementarity. Wave packets in space and time, and their physical significance.

b. **Schrodinger wave equation**: Development of wave equation: One-dimensional and extension to three dimensions inclusive of forces. Interpretation of wave function: Statistical interpretation, normalisation, expectation value and Ehrenfest's theorem. Energy eigen functions: separation of wave equation, boundary and continuity conditions. One dimensional: Square well and rectangular step potentials, Rectangular barrier, Harmonic oscillator.

Three dimensional: Particle in a box, Particle in spherically symmetric potential, Rigid rotator, Hydrogen atom.

UNIT-2: **General formalism of quantum mechanics**


The basic formalism: The fundamental postulates, expectation values and probabilities; quantum mechanical operators, explicit representation of operators, uncertainty principle. Matrix method solution of linear harmonic oscillator.


UNIT-3


b. **Theory of scattering**: Scattering cross-section, wave mechanical picture of scattering, scattering amplitude. Born approximation. Partial wave analysis: phase shifts, scattering amplitude in terms of phase shifts, optical theorem; exactly soluble problem- scattering by square well potential.

c. **Time-dependent phenomena**

Perturbation theory for time evolution, first and second order transition amplitudes and their physical significance. Applications of first order theory: constant perturbation, wide and closely spaced levels-Fermi’s golden rule, scattering by a potential. Harmonic perturbation: interactions of an atom with electromagnetic radiation, dipole transitions and selection rules; spontaneous and induced emission, Einstein A and B coefficients. Sudden approximation.
UNIT-4


b. Angular momentum: Definition, eigenvalues and eigenvectors, matrix representation, orbital angular momentum. Addition of angular momenta, Clebsch-Gordon coefficients for simple cases: \( j_1 = \frac{1}{2}, j_2 = \frac{1}{2} \) and \( j_1 = 1, j_2 = \frac{1}{2} \).

UNIT-5


REFERENCE BOOKS:

UNIT-1

a. **One electron System:** Quantum states of one electron atoms, atomic orbitals, hydrogen spectrum. Spectra of alkali elements, spin-orbit interaction and fine structure in alkali spectra. (Ref: 1, 6, 7)

b. **Two electron Systems:** LS-coupling, equivalent and non-equivalent electrons, spectral terms, Pauli exclusion principle, coupling schemes for two electrons, interaction energies for LS coupling, fine structure splitting for sp electron configuration, Lande interval rule. jj-coupling- spectral terms, interaction energies for jj-coupling, fine structure splitting for sp electron configuration. Qualitative consideration of selection and intensity rules for LS and jj-coupling. Hyperfine structure for one and two electrons and Lande interval rule. (Ref: 1, 6, 7)

UNIT-2

a. **Weak magnetic field effects:** Normal and anomalous Zeeman effect, magnetic moment of a bound electron and Lande g-factor, magnetic interaction energy, selection rules, Zeeman pattern for principal series doublet, intensity rules. Zeeman effect for two electrons-magnetic moment of the atom and g-factors, expression for magnetic interaction energy, selection rules, Zeeman pattern transitions for diffuse-series singlet, intensity rules. (Ref: 1, 6, 7)

b. **Strong magnetic field and Electric field effects:** Paschen-Back effect, expression for total energy shift, transitions for principal series doublet. Qualitative treatment of Paschen-Back effect and complete Paschen-Back effect for two electrons. Isotope structure. Stark effect-first and second order Stark effects in hydrogen. Width of spectral lines (qualitative). (Ref: 1,6,7)

UNIT-3: Microwave, Infra-red spectra,

UV-Visible spectra

Types of molecules- linear, symmetric top, asymmetric top and spherical top molecules. Theory of rotational spectra for rigid and non-rigid rotator diatomic molecules, energy levels, intensity of rotational lines. Microwave spectrometer and applications.

Vibrational energy of diatomic molecule as simple harmonic and anharmonic oscillators, Morse potential energy curve, energy levels and vibrational spectra. Diatomic molecule as a vibrating-rotator, vibration-rotation spectra-P,Q,R branches. IR- spectrometer and applications. (Ref: 2-7)
UV-Visible spectra


UNIT-4

a. Properties of Nucleus: Nuclear constitution. The notion of nuclear radius and its estimation from Rutherford's scattering experiment; the coulomb potential inside the nucleus and the mirror nuclei. The nomenclature of nuclei, and nucleon quantum numbers. Nuclear spin and magnetic dipole moment. Nuclear electric moments and shape of the nucleus.

b. Nuclear Forces: General features of nuclear forces. Bound state of deuteron with square well potential, binding energy and size of deuteron. Deuteron electric and magnetic moments - evidence for non-central nature of nuclear forces. Yukawa's meson theory of nuclear forces.


d. Nuclear Models: The shell model; Evidence for magic numbers, energy level, scheme for nuclei with Infinite Square well potential and the ground state spins. The extreme single particle prediction of nuclear spin and magnetic dipole moments -Schmidt limits. The liquid drop model: Nuclear binding energy, Bethe-Weizsacker's semi empirical mass formula; stability limits against spontaneous fission and nuclear decay.

UNIT-5


c. **Nuclear Energy**: Fission process, fission chain reaction, four factor formula and controlled fission chain reactions, energetics of fission reactions, fission reactor. Fusion process, energetics of fusion reactions; Controlled thermonuclear reactions; Fusion reactor. Stellar nucleo synthesis.

d. **Fundamental Interactions and Elementary Particles**: Basic interactions and their characteristic features. Elementary particles, classification; Conservation laws in elementary particle decays. Quark model of elementary particles.

**REFERENCE BOOKS:**

1. Introduction to Atomic Spectra: H E White, McGraw Hill,
4. Spectroscopy, Vols. 1, 2 and 3: B P Straughan and S Walker, Chapman and Hall
8. The Atomic Nucleus: R D Evans (TMH).
UNIT-1

a. **Crystal structure**: Crystal systems, Crystal classes, Bravais lattice. Unit cell: Wigner-Seitz cell, equivalent positions in a unit cell. Notations of planes and directions. Atomic packing: packing fraction, Co-ordination number. Examples of simple crystal structures: NaCl, ZnS and diamond. Symmetry operations, point groups and space groups. (Ref: 1-3)


d. **Lattice vibrations**: Vibrations of monoatomic lattices. First Brillouin zone. Quantization of lattice vibrations - Concept of Phonon, Phonon momentum. Specific heat of lattice (qualitative). (Ref: 1-3)

UNIT-2


b. **Defects in solids**: Point defects: Schottky and Frenkel defects and their equilibrium concentrations. Line defects: Dislocations, multiplication of dislocations (Frank-Read mechanism). Plane defects: grain boundary and stacking faults. (Ref: 1-3)

c. **Semiconductors**: Intrinsic and extrinsic semiconductors, concept of majority and minority carriers. Statistics of electrons and holes, electrical conductivity. Hall effect. Experimental determinations of resistivity of semiconductor by four probe method. (Ref: 1 and 4)

d. **Superconductors**: Superconductivity, Zero resistance,. Meissner effect, Critical field, Classification into Type I and Type II, Thermodynamics of superconducting transition, Electrodynamics of superconductors. (Ref: 1 and 2)
UNIT-3

a. **Introduction:** Origin of Nanotechnology, Nano materials, Types of nonmaterials, Surface area to volume ration, Quantum confinement effect, band theory of nonmaterials. Physical and chemical properties of nonmaterials.

b. **Synthesis of nanomaterials:** Bottom-up approach and Top-down approach with examples. Physical methods: Inert gas condensation, Arc Discharge, RF-plasma, plasma arc technique, electric explosion of wires, lasers ablation, laser pyrolysis, ball milling, molecular beam epitaxial, electro deposition. Sol-gel technique, Combustion synthesis, ultrasonic precipitation process, chemical vapour deposition.

c. **Characterization of Nanomaterials**


*Surface characterization Techniques:* Scanning electron microscopy (SEM), Transmission electron microscopy, Basic principles and applications of scanning probe techniques (SPM), Atomic force microscopy, and scanning tunneling microscopy.

*Spectroscopic techniques:* UV-Visible spectroscopy, Infrared (IR) & Fourier Transform infrared (FTIR) Spectroscopy, Raman Spectroscopy techniques: Photo luminescence Spectroscopy.


UNIT-4


b. **Inorganic nanostructures:** Overview of relevant semiconductor physics - Quantum confinement in semiconductor nanostructures - The electronic density of states - Fabrication techniques - Physical processes in semiconductor nanostructures - The characterisation of semiconductor nanostructures, Applications of semiconductor nanostructures.

UNIT-5: **Nanotechnology and Society**

Introduction to Societal Implications of Nanoscience and Nanotechnology, Nanotechnology Goals: Knowledge and scientific understanding of nature, Industrial manufacturing, materials and products, Medicine and the human body, Sustainability: Agriculture, water, energy, materials and clean environment, Space exploration, National
security, Moving into the market.

**REFERENCE BOOKS:**

2. Introduction to Solid State Physics, C. Kittel, Wiley Eastern.
12. Fundamentals of Nanoelectronics by George W. Hanson (Perason education, New Delhi).
13. MEMS & Microsystems: Design & Manufacture by Tai-Ran Hsu, (Tata Macgraw Hill, New Delhi).
UNIT-1

a. **Engineering Materials:** Materials science and engineering, Classification, Levels of structure, Structure-property relationship in materials. (Ref: 1, 2 and 3)

b. **Structure of Solids:** The crystalline and Non-crystalline states, Covalent solids, Metals and alloys, Ionic solids, The structure of silica and silicates. (Ref: 1, 2 and 3)

c. **Crystal growth:** Crystal growth from melt: Bridgemann technique, Crystal pulling by Czochralski's method, Growth from solutions, Hydrothermal method, Gel method, Zone refining method of purification. (Ref: 2 and 5)

d. **Crystal imperfections:** Point imperfections, Dislocation, Edge and Screw dislocation, Concept of Burger vector and Burger circuit, Surface imperfections, Colour centres in ionic solids. (Ref: 1, 2 and 3)

UNIT-2

**Solid Phases and Phase diagrams:** Single and multiphase solids, Solid solutions and Hume-Rothery rules, Intermediate phase, The intermetallic and interstitial compounds, Properties of alloys: solid solutions and two component alloy systems; Phase diagram, Gibbs phase rule, Lever rule; First, second and third order phase transitions with examples; Some typical phase diagrams: Pb-Sn and Fe-Fe$_2$O$_3$, Eutectic, eutectoid, peritectic and peritectoid systems. (Ref: 1, 2 and 3).

a. **Phase transformation:** Time scale for phase changes; Nucleation and growth, nucleation kinetics; Growth and overall transformation kinetics, Applications: transformation in steel; Precipitation processes, solidification and crystallization; Glass transition, recovery, recrystallization and grain growth. (Ref: 1, 2 and 3)

b. **Diffusion in Solids:** Theory of diffusion, Self-diffusion, Fick's law of diffusion, Kirkindal effect, Activation energy for diffusion, Applications of diffusion. (Ref: 1, 2, 3)

UNIT-3: **Electrical and mechanical properties**


**PROPERTIES OF NANOMATERIALS**
UNIT-4: Nanooptics

Absorption: direct and indirect bandgap transitions - Emission: photoluminescence and Raman Scattering, Emission: Chemiluminescence and Electroluminescence, Shape dependent optical properties, Optical absorption, Optical emission, Surface plasmon resonance (SPR) - Surface enhanced Raman scattering (SERS).

Nanocatalysis

Introduction, nanomaterials in catalysis, metals, recent progress, nanostructured adsorbant, metals, controlled pore size materials, pelletized nanocrystal, nanoparticles as new chemical reagents, metals, metal oxide reactions, nanocomposite polymers, fluids, inks and dyes, block co polymers and dendrimers, nanocrystal superlattices.

UNIT-5: Nanomagnetism

Introduction, fundamental concepts, magnetic materials, dia, para and ferromagnetism - magnetic phenomena in ferromagnetic materials, magnetic anisotropy, magnetic domains, hysteresis small particle magnetism, single domain particles, coercivity of single domain particles, superparamagnetism, the coercivity of small particles - review of some issue in nanoscale magnetism.

REFERENCE BOOKS:
UNIT-1: Liquid crystals
Introduction, classification of liquid crystals, thermotropic liquid crystals (rod like molecules), chirality in liquid crystals, nematic, cholestric and smectic mesophases, polymorphism in thermotropic liquid crystals, polymer liquid crystals and their applications, distribution functions and order parameter, measurement of order parameters by X-ray diffraction.

a. Theories of phase transition: Nature of phase transitions and critical phenomena in liquid crystals, Mier-Saupé theory for nematic-isotropic and nematic-smectic A transitions, optical properties of cholesteric liquid crystals, the blue phases, pressure induced mesomorphism.

b. Continuum Theory: Continuum theory of the nematic state, liquid crystals in electric and magnetic fields, magnetic coherence length, Freedericksz transitions, field-induced cholesteric-nematic transition, continuum theory of smectic A Phase, Reentrant phenomena in liquid crystals.

UNIT-2: Ferroelectric and discotic liquid crystals
Ferroelectric liquid crystals, applications of ferroelectric liquid crystals, discotic liquid crystals, columnar liquid crystal, the discotic nematic phase. Lyotropic liquid crystals, constituents of lyotropic liquid crystals, structures of lyotropic liquid crystal phases, biological membranes.

UNIT-3: Identification of liquid crystal phases and liquid crystal technology
Identification of nematic, smectic and chiral liquid crystal phases by optical polarizing microscopy (Visual appearance and texture), Phase identification with Differential Scanning Calorimetry, liquid crystal display, the twisted nematic liquid crystal displays, liquid crystal displays using polymers, applications of liquid crystals.

POLYMER SCIENCE

UNIT-4
a. Introduction and methods of synthesis: Macromolecular concepts, structural feature of polymers, correlation between structure and properties of various polymerization methods.

b. Industrial methods for polymer production & characterization techniques: Bulk, solution, suspension and emulsion polymerization techniques, interfacial, melt and solution polycondensation, some other miscellaneous techniques.

c. Concepts on chemical & physical properties
Chemical bonds, polymer solubility, chemical reactivity, polymer degradations, toxicity, diffusion and permeability, flammability, recycling, reclamation etc.
UNIT-5: Rheology of polymers

Stress and strain, types of deformation, Newtonian and non-newtonian fluid, apparent viscosity, the power law, molecular hole concept, Weisenberg effect, melt fracture, ideal elastic behaviour, viscoelastic behaviour, plastic stress-strain behaviour, creep, toughness, measurement methods.

a. Microstructure of polymers and order in crystalline polymers: Microstructures based on chemical and geometrical structures, properties related to structures, crystalline and non-crystalline polymers degree of crystallinity, factors affecting crystallinity and crystallisability, helix structure, spherulites

b. Transition temperatures & properties of polymers: Glass transition temperature, melting temperature, measurement methods, factors affecting transition temperatures as well as properties, Heat distortion temperature.

REFERENCE BOOKS:

1. Liquid Crystals by S. Chandrasekhar.
2. Thermotropic Liquid Crystals by Vertogen and Jeu.
3. The Physics of Liquid Crystals by de Geenes and Prost.
4. Ferroelectric Liquid Crystals by Goodby et al.
5. Polymer Science by V. R. Gowarikar.
6. Polymer Science and Tech. of Plastics and Rubber by P. Ghosh.
7. Plastic materials and processing by A. Brent strong.
8. Introduction to polymers by Young & Lovell.
UNIT - 1: Solvent and Environmental Effects on Fluorescence spectra
Stokes' shifts and solvent relaxation, general and specific solvent effects, other mechnisms for spectral shifts. Lippert equation, Derivation of Lippert equation, Applications of Lippert equation, Specific solvent effects. Temperature effects, Additional factors that affects the emission spectra - locally excited and internal charge transfer states, excites state intramolecular proton transfer, effects of viscosity, probe-probe interaction and effect of solvent mixtures.

UNIT - 2: Fluorescence Quenching

Mechanisms and Dynamics of Fluorescence Quenching
Introduction, comparision of quenching and resonance energy transfer, distance dependence of resonance energy transfer and quenching, encounter complexes nd quenching efficiency, mechanisms of quenching: Intersystem crossing or heavy atome effect, electron exchange, photoinduced electron transfer. Transient effects in quenching.

Fluorescence Sensing
Optical Clinical Chemistry and spectral observable, spectral observable for fluorescence sensing, Mechanism of sensing, sensing collisional quenching - oxygen sensing, chloride sensors, energy transfer sensing - pH and pCO₂ sensing by energy transfer, glucose sensing by energy transfer, ion sensing by energy transfer, theory of energy transfer sensing.

UNIT-3:
X-RAY CRYSTALLOGRAPHY
Crystal and Symmetry: Growth of single crystals, different methods, Optical properties, ferroelectric, piezoelectric, thermal properties of crystal, Crystal system- Bravais lattices- point group and space group, symmetry elements.
Quasicrystals: definition, preparation, symmetry orientation order in quasicrystals, Quasi-periodic space tiling procedure.
Macromolecules: definition, examples of macromolecules or Bio-molecules-symmetry.
X-rays: Production, white radiation characteristics, radiation - absorption edge, filters - absorption by crystals.

UNIT-4: DIFFRACTION OF X-RAYS
Direct and reciprocal lattice, Ewald's sphere and Bragg's law, Spacing formula,Transformation equations, Interpretation of rotation photograph.
Scattering of X-rays by a distribution of electron, structure factor, calculation of electron density function, Fourier synthesis, the crystal symmetry and x-ray diffraction pattern, Friedel's law and its break down.
Electron and neutron diffraction, comparison with X-ray diffraction, significance of electron and neutron diffraction, characterization of quasicrystalline sample using electron
diffraction.


UNIT-5:

INTENSITY DATA COLLECTION, STRUCTURE SOLUTION AND REFINEMENT

The single crystal diffractometer method, intensity data collection, corrections to intensity data- Lorentz, polarization, spot shape and absorption effects, primary and secondary extinction effects, absolute scaling and temperature factors.

Fourier techniques, Phase problem, Patterson function and its significance, Heavy atom methods, Isomorphous replacement method, anomalous scattering method, direct methods.

Cyclic Fourier refinement, the difference Fourier refinement, correction for series termination effects, temperature correction, Least squares refinement.

Derived results- bond lengths, bond angles, standard deviations in bond lengths and angles, comparison and averaging of bond lengths and angles, least square planes, absolute configuration and thermal motion.

Text Book:

References:
UNIT-1

a. Coherence: Coherence, spatial and temporal coherence, measurement of spatial and temporal coherence, coherence time, coherence length, line width and monochromaticity; coherence time and line width via Fourier analysis, complex degree of coherence and fringe visibility in Young's double hole experiment.

b. Laser rate equations: Basic structure of a Laser, theory of laser oscillations, round-trip power gain and threshold condition. Rate equations for two, three and four level lasers; variation of laser power around threshold, optimum output coupling.


d. Line broadening mechanisms and laser modes: Line shape broadening: Doppler broadening, collision broadening, natural radiative lifetime broadening, homogeneous and inhomogeneous broadening.

Laser modes: Longitudinal and transverse modes, experimental arrangement for mode selection. Gain saturation, gain saturation in homogeneously and inhomogeneously broadened lasers, hole burning.

UNIT-2


b. $Q$-switching and mode locking techniques: $Q$-switching, production of a giant pulse; methods of $Q$-switching: Mechanical shutters, electro-optical shutters, acousto-optic $Q$-switches, shutter using saturable dyes, peak-power emitted during the pulse, giant pulse dynamics.

Mode locking: Active and passive mode locking techniques, ultrashort laser pulses, Laser amplifiers.

c: Types of Lasers

UNIT-3

a. **Cell biophysics**: Cell doctrine; General organisation and composition of the cells.

b. **Bioenergetics**: The biological energy cycle and the energy currency. Thermodynamic concepts; Free energy of a system- Gibb's free energy function. Chemical potential and redox potentials. Energy conversion pathways-Kreb's cycle; respiratory chain, oxidative phosphorylation. Photosynthesis- photosynthetic apparatus; mechanisms of energy trapping and transfer; photophosphorylation.

c. **Membrane biophysics**: Cell membranes- structure, function and models; Transport across membranes- passive and active processes; Chemiosmotic energy transduction- van't Hoff equation; Ionic equilibrium-electrochemical potential; Nernst's equation; Flow across membranes- membrane permeability.

d. **Neurophysics**: The nervous system. Synaptic transmission; information processing in neuronal systems. Physical basis of biopotentials; Action potential; Nernst-Planck equation. Nerve excitation and conduction; Hodgkin-Huxley model.

UNIT-4: **Physiological biophysics**

Physics of sensory organs- the transmission of information; Generator potentials. Visual receptor- mechanism of image formation; Auditory receptor- mechanism of sound perception; Mechanisms of chemical, somatic and visceral receptors. Mechanism of muscle contractility and motility. Temporal organisation- basis of biorhythms.

UNIT-5

a. **Biophysics of the immune system**: The immune system; cellular basis of immunal responses; antibodies and antigens; Immunological memory.

b. **Genetic engineering**: Gene-Structure, expression and regulation; Genetic code and genome organisation; Recombinant technology. Transgenic systems. Cybernetics- Genetic information and the brain; neural nets.

**REFERENCE BOOKS:**

UNIT-1: Analog ICs and Applications
Integrated Circuits, microelectronics technology; IC packages relevant to BJT and MOS. Basic characteristics of operational amplifier: Offset error voltage and currents, inverting and non-inverting amplification using closed loop concept, input and output impedance. Adder and subtractor circuits, voltage to current converter, current to voltage converter, analog integration and differentiation, analog computation, logarithmic and exponential amplifiers, comparators and voltage regulators. Waveform generators: RC-oscillator, Wein bridge oscillator, multivibrators, square and triangle wave generator, Schmitt trigger. Digital to analog convertor, analog to digital converters. (Ref.: 1 and 2)

UNIT-2: Digital ICs and Applications
Combinational digital system: Binary adders, arithmetic function, decoder-demultiplexer, data selector, multiplexer, encoder, read only memory (ROM), PROMs and EPROMs. Sequential circuits and systems: 1 bit memory, clocked flip-flops, S-R, J-K, T and D-type flip-flops, shift registers, asynchronous and synchronous counters and their applications (qualitative). Microprocessors: architecture and operation, memory, input/output, timing instructions. (Ref. 1-5)

UNIT-3: Transducers

UNIT-4: Physical methods of analysis
REFERENCE BOOKS:
2. Electronic Fundamentals and Application: J D Ryder.
3. Digital Principles and Application: Malvino and Leach.