PHYSICS

UNIT 1: MATHEMATICAL METHODS

Differential Equations: recurrence formulae for $J_n(x)$ - generating function for $J_n(x)$ Hermite differential equation Hermite's polynomials – Generating function of Hermite polynomials Recurrence formulae for Hermite polynomials - Rodrigue's formula – Complex variables: analytic function - C-R differential equations - C-R equations in polar form –Laplace's equation – examples - Cauchy's integral Theorem and formula - Taylor's series - Laurent's series - Singularities of an analysis function - Residues and their evaluation – Cauchy residue theorem - Evaluation of definite integrals (trigonometric functions of cos θ and sin θ only) Group theory : concept of a group - Abelian group – Generators of finite group - Cyclic groups Group multiplication table - Rearrangement theorem – Sub groups - Lagrange's theorem for finite group conjugate elements and classes - Group of symmetry of an equilateral triangle Group of symmetry of square – Representation of a group – Reducible and irreducible representation - Schur's lemmas - Orthogonality theorem - Tensor, beta and gamma functions: scalars, Contravariant and covariant vectors – Tensors of higher rank – Algebraic operation of tensors - Mixed tensor – Symmetric and anti-symmetric tensors – Quotient law - Beta and Gamma functions : Definitions - Symmetry property of Beta function – Other forms of Beta function - Evaluation of Gamma function – Other forms of Gamma function – Relation between Beta and Gamma functions - Examples.

UNIT 2: CLAASICAL MECHANICS AND RELATIVITY

Lagrangian formulation: Generalized coordinates – Mechanics of a particle and system of particles (momentum and energy) D'Alemberts principle - Lagrange's equations – Applications (linear harmonic oscillator, simple pendulum isotropic oscillator and electrical circuit) Hamilton's equations - Applications (simple pendulum, compound pendulum and 20 harmonic oscillator) – Deduction of Hamilton's principle - Hamilton's variational principle – Principle of Least action. Canonical transformations : Equation of canonical transformations – Infinitesimal contact transformations – Lagrange and Poisson brackets as Canonical invariants – Equations of motion in Poisson bracket form - Jacobi's identity – Relation between Lagrange and Poisson brackets – Action angle variables - Euler's angles – Angular velocity of a rigid body - Euler's equation of motion – Relativity : Einstein's Mass – Energy relation – Relation between momentum

and energy – Four vectors – Four velocity – Energy – Momentum four vectors – Four force Relativistic classification of particles – Relativistic Lagrangian, Hamilltonian function relativistic Lagrangian Hamiltonian of a charged particle in an E.M field.

UNIT 3: QUANTUM THEORY AND ITS APPLICATIONS

General Principles of Quantum Mechanics: Wave packet – Time dependent and time independent Schrodinger equation - Linear vector space – Linear operator - Eigen function and Eigen values - Hermitian operator – Postulates of Quantum Mechanics – Simultaneous measurability of observables – General uncertainty relation - Dirac's notation – Applications : Square well potential with rigid walls and finite walls - Square potential barrier - Alpha emission – Bloch waves in a periodic potential – Kronig - Penny square-well periodic potential Linear harmonic oscillator: Schrodinger method - Operator method - Delta function - Particle moving in a spherically symmetric potential - System of two interacting particles – Rigid rotator Hydrogen atom - Hydrogen orbitals - Angular Momentum : The angular momentum operators Spin vectors for Spin-(1/2) system – Addition of angular momenta - Time independent and dependent Perturbation theory – Basic concepts – Non degenerate energy levels – Anharmonic oscillator: First-order correction – Ground state of Helium – Effect of electric field on the ground state of hydrogen - Transitions to continuum states – Absorption and emission radiation Einstein's A and B coefficients - Selection rules – Theory of Scattering : Scattering cross- section Scattering by a central potential : partial wave analysis - Significant number of partial waves Scattering by an attractive square - well potential - Breit-Wiger formula – Scattering length Expression for phase shifts – Integral equation – The Born approximation – Scattering by screened Coulomb potential - Validity of Born approximation – Laboratory and centre of mass co-ordinate system

UNIT 4: ELECTROMAGNETIC THEORY

Electrostatics – Electric charge – electric charge density - Coulomb's law – Electric intensity -Electric potential – Gauss law- Applications – Boundary value problems in electrostatics – Methods of separation variables in Cartesian co-ordinates. Magneto statics - Ampere's circuital law - Magnetic scalar potential – Magnetic vector potential – Magnetization and Magnetization current – Magnetic intensity – Magnetic susceptibility. Equation of continuity – Displacement current - Maxwell's equation – Derivations – energy in electromagnetic fields - (poynting's theorem). Maxwell's equation in terms of electromagnetic potentials – Concept of gauge-Lorentz gauge.

Plane electromagnetic wave and their propagation – Interaction of electromagnetic wave with matter on microscopic scale. Retarded potentials - Radiation from a linear antenna.

UNIT 5: THERMODYNAMICS AND STATISTICAL MECHANICS

Thermodynamics as phenomenological science – Thermodynamic systems - Closed, open, isolated systems – Thermodynamic processes - Adiabatic, isothermal, isochoric, isobaric, isentropic, cyclical and free expansion processes - Reversible, irreversible and Quasi-static processes – Equation of state – Intensive and extensive variables - The *P*-V diagram. Conversion of work into heat and vice-versa – Efficiency - Kelvin-Planck statement of the second law of thermodynamics – Clausius statement of the second law – Carnot cycle – Carnot refrigerator - Carnot's theorem and corollary. Equation of state of a gas from Avogadro's law – Ideal gas equation – Specific heat, internal energy and enthalpy of an ideal gas – Entropy change of an ideal gas – Reversible adiabatic process - Reversible isothermal process. Concept of entropy – Entropy of an ideal gas – The *T*-*S* diagram - Entropy, reversibility and irreversibility. Microstate and Macrostate of macroscopic system, Phase space and Phase space density, Liouville theorem. Canonical ensemble canonical partition function. – Grand canonical ensemble - Density operator, Spin statistics connection, Grand partition function for ideal Bose and Fermi gases, Bose-Einstein, Fermi-Dirac and Maxwell-Boltzmann distributions, Application to Black body radiation: Bose theory(a) Debye theory of specific heat(b) Bose-Einstein condensation – Phase transitions.

UNIT 6: Atomic and Molecular Physics

Electromagnetic spectrum – Absorption or Emission of radiation - Line width - Natural line broadening – Doppler broadening – Pressure broadening - Removal of line broadening - X-ray Spectra – Emission and absorption spectra of X-rays. Regular and irregular doublet laws - X-ray satellites – Photoelectron spectroscopy - Ultraviolet photoelectron spectrometers – XPS techniques and Chemical information from photoelectron spectroscopy – Auger electron spectroscopy. Infrared Spectroscopy – Vibrational Energy of a Diatomic molecule - The Diatomic Vibrating Rotator - The Vibrations of Polyatomic molecules – Rotation – Vibration spectra of Polyatomic molecules – Analysis by Infra-red Techniques – IR spectrophotometer Fourier Transform - IR spectrophotometer – Applications - Frank-Condon principle and dissociation energy. Raman Spectroscopy – Theories of Raman scattering – Rotational

Raman Spectra – Vibrational Raman Spectra – Mutual Exclusion principle – Raman Spectrometer Polarization of Raman Scattered light – Structural determination from Raman and IR spectroscopy - Near IR – FT- Raman spectroscopy. Laser *Spectroscopy* - Basic principles: Comparison between conventional light sources and lasers – Saturation - Excitation methods – Detection methods – Laser Wavelength Setting – Doppler Limited Techniques. Nuclear Magnetic Resonance Spectroscopy - Basic principles – Magnetic resonance – Relaxation processes – Pulsed (Fourier Transform) NMR - Wide line NMR spectrometers – Spectra and molecular structure – Chemical shifts - Spin-spin coupling – Integration - Applications. - Principles of Mossbauer spectroscopy – Chemical shifts – Quadrupole splitting and Zeeman splitting. Applications of Mossbauer spectroscopy.

UNIT 7: CONDENSED MATTER PHYSICS

Elements of X-ray Crystallography and defects in solids – Miller indices – Point groups - Space group – Reciprocal lattice - Bragg's law interpretation – Structure factor - Fcc and Bcc structures – Electron density distribution experimental techniques for crystal structure studies (powder, Laue, rotation crystal method) – Electron and neutron diffraction methods – Point defects - Color centres – Line defects – Edge dislocation – Screw dislocation – Dislocation method. Semiconductors – Intrinsic semiconductor and extrinsic semiconductor - Mobility, drift velocity and conductivity of intrinsic and extrinsic semiconductors – Carrier concentration in intrinsic and extrinsic semiconductors - Band model. Magnetic properties – Magnetic permeability – Theory of diamagnetism - Langevin's theory of paramagnetism – Weiss theory – Paramagnetic susceptibility of a solid – Calculation of susceptibility – Quantum theory of paramagnetism determination of susceptibility – Para and diamagnetic materials - Ferromagnetism Spontaneous magnetism in ferromagnetism - Curie-Weiss law – Ferromagnetic domains - domain theory Antiferromagnetism - Structure of ferrites- Dielectric properties - Microscopic concepts of polarization - Langevin's theory of polarization in polar dielectrics - Local fields in liquids and solids – Evaluation of local fields for cubic structure – Clausius – Mossotti relation - Lorentz formula - Ferroelectricity - Dipole theory of ferroelectricity – Classification of ferroelectric materials – Antiferroelectricity - Piezoelectricity - The complex dielectric constant and dielectric loss.

UNIT 8: NUCLEAR AND PARTICLE PHYSICS

Elements of nuclear Structure and Systematics : Theories of nuclear composition (proton-electron theory, proton-neutron theory) – Mass spectroscopy – Bainbridge and Jordan mass spectrograph - Nier's mass spectrometer – Deuteron – Magnetic and quadra pole moment of deuteron - Ground state of deuteron – Excited state of deuteron - The meson theory of nuclear force - Yukawa potential – Properties of Stable Nuclei and Nuclei models - Semi empirical mass formula - Nuclear models - Shell models –Magic numbers – Single particle model – Collective model – liquid drop model - Magnetic moments and shell model – Prediction of angular momenta of nuclear ground state - Nuclear Reaction Studies. Conservation laws for nuclear reactions – Nuclear energy - Photo nuclear reaction – fission process – cross sections – Bohr Wheeler theory - Elementary Particles – Classification of elementary particles – Fundamental interactions - Electromagnetic, strong, weak gravitational interactions - Parameters of elementary particles - Conservation laws – Quarks theory.

UNIT 9: ELECTRONICS

Semiconductor Diodes: Operation, characteristics and applications of Zener and Avalanche, Varactor, Schottky - barrier, Tunnel diodes; Construction, operation and Characteristics of BJT, FET and MOSFET-FET amplifier – Negative Resistance and Devices -Uni-Junction transistor and its characteristics - UJT relaxation oscillator - UJT applications - Tunnel diode characteristics and applications - Gunn Diode mechanism – Characteristics and applications SCR - characteristics and applications. IC-Fabrication Technology – Monolithic IC process refining and growth of silicon crystals - Silicon Wafer – Operational Amplifier – Characteristics of ideal and practical Op Amps – Parameters of Op Amp – Theory of inverting amplifier – virtual ground - Theory of non-inverting amplifier – Sinusoidal oscillators – Phase shift oscillator - Wein Bridge oscillator – Crystal oscillator – Multi vibrator – Comparator – Schmitt trigger - Square wave and triangular wave generators – Active filters – Digital Electronics Fundamentals – Number systems - Binary arithmetic – 8421 code-excess – grey code –ASCII code – Logic gates and logic circuits - Boolean algebra – De Morgan's theorems – Arithmetic circuits – Simplification using Karnaugh's map - problems.

UNIT 10: EXPERIMENTAL PHYSICS

Measurement of energy and time using electronic signals from the detectors and associated instrumentation – Signal processing – A/D conversion – Multichannel analyzers – Time-of-flight Technique – Coincidence Measurements – True to chance ratio – Correlation studies. Error Analysis and Hypothesis testing – Propagation of errors - Plotting of Graph – Distributions - Least squares fitting – Criteria for goodness of fits – Chi square test - Measurement of fundamental constants : e,*h*,c - Measurement of high and low resistances, inductance and capacitance - Detection of X-rays, Gamma rays, charged particles, neutrons - Ionization chamber – Proportional counter – GM counter – Scintillation detectors – Solid State detectors - Vacuum Techniques – Basic idea of conductance, pumping speed – Pumps : Mechanical Pump - Diffusion pump – Gauges – Thermocouple gauge – Penning gauge – Pirani gauge – Hot Cathode gauge - Low temperature systems - Cooling a sample over a range up to 4 K - Measurement of low temperatures.