

UNIT I**Mathematical Methods of Physics**

Dimensional analysis. Vector algebra and vector calculus-Gauss divergence theorem, Greens theorem, Stokes theorem. 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). 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. 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. Equation of continuity - Application to hydrodynamics, equation of heat flow. Finite difference methods. Tensors. Introductory group theory: $SU(2)$, $O(3)$.

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- Symmetrical top and Fast and sleeping top - moment of inertia tensor. Non-inertial frames and pseudoforces. Variational principle. Generalized coordinates. D'Alembert's principle and Lagrangian equations of motion - Hamiltonian formalism and equations of motion - Conservation laws and cyclic coordinates - Liouville's theorem. Periodic motion: small oscillations, normal modes. Special theory of relativity- Lorentz transformations, relativistic kinematics and mass-energy equivalence - Invariance of Maxwell's equations - Relativistic Lagrangian and Hamiltonian for a free particle. Canonical transformations- Poisson brackets- Hamilton-Jacobi theory - action-angle variables. Canonical transformations- Poisson brackets- Hamilton-Jacobi theory - action-angle variables.

UNIT II**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- Poynting's theorem - Lorentz invariance of Maxwell's equation.. Scalar and vector potentials, gauge invariance. Electromagnetic waves in free space- Dynamics of charged particles in static and uniform electromagnetic fields. . Dielectrics and conductors. Radiation- from moving charges and dipoles and retarded potentials. Reflection and refraction, polarization, Fresnel's law, interference, coherence, and diffraction. Dynamics of charged particles in static and uniform electromagnetic fields. Dispersion relations in plasma. Transmission lines and wave guides

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

UNIT III

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

UNIT IV

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
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.

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.

UNIT V

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.

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.