

Part B - Syllabus

PHYSICS (PHY)

Mathematical Methods: Vector calculus: gradient, divergence, curl, Gauss's, Stokes', and Green's theorems; coordinate systems: Cartesian, cylindrical, spherical; complex analysis: analytic functions, Cauchy-Riemann equations, contour integration, residue theorem; linear algebra: eigenvalues, eigenvectors, and diagonalisation; ordinary and partial differential equations; Fourier series and transforms; Laplace transforms; special functions: Legendre, Bessel, Hermite, and Laguerre polynomials; Green's functions; tensors: contravariant and covariant; numerical methods: Newton-Raphson, Runge-Kutta, and numerical integration.

Classical Mechanics: Newtonian mechanics; Lagrangian mechanics: generalised coordinates and equations of motion; Hamiltonian mechanics and phase space; variational principles; rigid body dynamics: Euler angles, moment of inertia tensor; central force problems: Kepler's laws and orbital mechanics; small oscillations and normal modes; non-inertial frames: pseudo-forces and Coriolis effect; Special Theory of Relativity: Lorentz transformations, time dilation, length contraction, relativistic energy and momentum; canonical transformations; Poisson brackets; Hamilton-Jacobi theory.

Electromagnetic Theory: Electrostatics: Coulomb's law, Gauss's law, electric potential, boundary value problems; dielectric materials; magnetostatics: Biot-Savart law, Ampere's law, vector potential; Maxwell's equations; EM wave propagation; plane waves: polarisation, reflection, refraction; waveguides: TE and TM modes; cavity resonators; radiation: electric dipole, retarded potentials, Lienard-Wiechert potentials; radiation reaction; Poynting vector and EM energy; Fresnel coefficients.

Quantum Mechanics: Origins of quantum theory; wave-particle duality; Schrodinger equation (time-dependent and independent); operators and observables; Heisenberg uncertainty principle; one-dimensional problems: potential well, harmonic oscillator, and tunnelling; angular momentum: orbital and spin; addition of angular momenta; hydrogen atom: exact solution and spectra; identical particles: Pauli exclusion principle; time-independent perturbation theory (degenerate and non-degenerate); variational method; WKB approximation; time-dependent perturbation theory: Fermi's golden rule and selection rules.

Statistical Mechanics: Phase space; classical statistical mechanics: microcanonical, canonical, and grand canonical ensembles; partition function; Maxwell-Boltzmann statistics; applications to ideal gas; quantum statistics: Bose-Einstein and Fermi-Dirac distributions; Bose-Einstein condensation; Planck's radiation law; Fermi energy and electronic heat capacity; thermodynamic functions from partition function; phase transitions: first and second order; Ising model and mean field theory; fluctuation-dissipation theorem; non-equilibrium thermodynamics basics.

Atomic and Molecular Physics: Vector atom model; quantum numbers and spectroscopic notation; many-electron atoms: Hund's rules; LS coupling and jj coupling; spectral terms and selection rules; Zeeman effect: normal and anomalous; Stark effect; hyperfine structure; molecular bonding: ionic, covalent, and van der Waals; molecular spectra: rotational, vibrational, and electronic; Born-Oppenheimer approximation; Raman spectroscopy; Frank-Condon principle; lasers: population inversion, gain, and types; non-linear optics: second harmonic generation and parametric processes.

Solid State Physics: Crystal structures: Bravais lattices, Miller indices, and X-ray diffraction (Bragg's law); reciprocal lattice and Brillouin zones; lattice vibrations: phonons, Debye and Einstein models; free electron theory: Drude and Sommerfeld models; band theory: Bloch theorem, effective mass, and band gap; semiconductors: carrier concentrations, p-n junction, and Hall effect; dielectric properties: polarisation mechanisms and ferroelectrics; magnetic properties: diamagnetism, paramagnetism,

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ferromagnetism, and antiferromagnetism; superconductivity: Meissner effect, London equations, BCS theory, type I and II, and Josephson junctions.

Nuclear and Particle Physics: Nuclear properties: size, charge distribution, binding energy, spin, parity, and magnetic moments; nuclear models: liquid drop, shell model, and collective model; radioactive decay: alpha, beta, and gamma decay laws; nuclear reactions: Q-value, cross-sections, compound nucleus model; nuclear fission: chain reaction and reactor physics; nuclear fusion: stellar nucleosynthesis; particle accelerators: cyclotron, synchrotron, and linear accelerator; particle detectors; elementary particles and Standard Model: quarks, leptons, gauge bosons; conservation laws; CP violation; neutrino oscillations.

Optics and Spectroscopy: Geometrical optics: reflection, refraction, and optical instruments; wave optics: interference (Young's double slit, thin films, Newton's rings, Michelson interferometer); diffraction: Fraunhofer and Fresnel; diffraction grating; resolving power; polarisation: Malus's law, birefringence, and optical activity; coherence; holography; optical fibre; spectroscopic methods: UV-Vis, IR, Raman, NMR, ESR, and X-ray spectroscopy; atomic and molecular spectroscopy; laser spectroscopy; LIDAR and remote sensing.

Electronics and Instrumentation: Semiconductor devices and circuits; op-amp applications; oscillators; digital logic and microprocessors; ADC and DAC; signal processing: filters and lock-in amplifiers; vacuum techniques; measurement of electrical, optical, and magnetic quantities; CRO, spectrum analyser, and signal generators; data acquisition; LabVIEW basics; error analysis and statistics in experimental physics; radiation measurement: GM counter, scintillation detector, and semiconductor detector.

Advanced Topics: Plasma physics: Debye length, plasma frequency, and MHD equilibrium; astrophysics: stellar structure, HR diagram, compact objects, and cosmology — Big Bang, CMB, dark matter; gravitational waves: detection and LIGO; quantum information: qubits, entanglement, and quantum gates; quantum optics: photon statistics and squeezed light; Bose-Einstein condensates; topological insulators and Weyl semimetals; spintronics and giant magnetoresistance; 2D materials: graphene and transition metal dichalcogenides; computational physics: Monte Carlo, molecular dynamics, and DFT.