



PHYSICS Ph.D. ENTRANCE EXAMINATION Syllabus

UNIT I: MATHEMATICAL PHYSICS

Matrices, determinants, eigenvalues and eigenvectors; Cayley-Hamilton theorem; Ordinary differential equations; Special functions: Legendre, Bessel, Hermite and Laguerre functions.

Fourier series; Fourier and Laplace transforms; Complex analysis; Taylor and Laurent series; poles, residues and contour integration; Probability theory and probability distributions; Green's functions.

Partial differential equations; Numerical and computational techniques; Tensors; Introductory group theory: SU (2) group.

UNIT II: CLASSICAL MECHANICS

Newton's laws and equations of motion, Dynamical systems, phase-space dynamics and stability analysis, Central force motion, Two-body collisions and scattering, Rigid-body dynamics and moment of inertia tensor, Non-inertial frames and pseudo-forces, Variational principle and generalized coordinates, Lagrangian and Hamiltonian formalisms, Conservation laws and cyclic coordinates, Small oscillations and normal modes, Poisson brackets and canonical transformations, Symmetry, invariance and Noether's theorem, Hamilton-Jacobi theory, Special theory of relativity and relativistic kinematics

UNIT III: ELECTROMAGNETIC THEORY

Electrostatics, Gauss's law, Laplace and Poisson equations, boundary-value problems, magnetostatics, Biot-Savart law, Ampere's theorem, electromagnetic induction, Maxwell's equations, boundary conditions, scalar and vector potentials, gauge invariance, electromagnetic waves, dielectrics, conductors, reflection, refraction and Fresnel laws. Polarization, interference, coherence and diffraction, motion of charged particles in electromagnetic fields, plasma dispersion, Lorentz invariance of Maxwell's equations, transmission lines, waveguides, radiation from moving charges and dipoles, and retarded potentials.

UNIT IV: QUANTUM MECHANICS

Wave-particle duality; Schrödinger equations; particle in a box and harmonic oscillator; coordinate and momentum representations; commutators, uncertainty principle Angular momentum, spin, addition of angular momenta, hydrogen atom and Stern-Gerlach experiment; perturbation theory and variational method, WKB approximation; Fermi's golden rule, selection rules, identical particles, Pauli exclusion principle, spin-statistics, spin-orbit coupling and fine structure.

Scattering theory, phase shifts, partial waves and Born approximation; Klein-Gordon and Dirac equations; semi-classical theory of radiation.

UNIT V: THERMODYNAMICS AND STATISTICAL PHYSICS

Laws of thermodynamics and consequences; thermodynamic potentials, Maxwell relations, chemical potential and phase equilibria; phase space, microstates, macrostates and statistical ensembles.

Partition functions, free energy, classical and quantum statistics; Bose-Einstein and Fermi-Dirac gases; detailed balance and Planck distribution. Phase transitions, diamagnetism, Para magnetism, ferromagnetism, Ising model and Bose-Einstein-condensation; diffusion, random walk and Brownian motion.

UNIT VI: ELECTRONICS

Semiconductor devices (diodes, junctions, transistors, field effect devices, homo- and hetero-junction devices). 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.

UNIT VII: ATOMIC AND MOLECULAR PHYSICS

Quantum states of electrons, electron spin, atomic spectra of helium and alkali atoms; relativistic corrections, hyperfine structure, isotopic shift and spectral-line broadening. LS and JJ coupling; Zeeman, Paschen–Back and Stark effects; electron spin resonance, nuclear magnetic resonance and chemical shift. Franck–Condon principle, Born–Oppenheimer approximation; electronic, rotational, vibrational and Raman spectra of diatomic molecules; selection rules. Lasers: spontaneous and stimulated emission, Einstein A and B coefficients, optical pumping, population inversion, rate equations, resonator modes and coherence length.

UNIT VIII: CONDENSED MATTER PHYSICS

Bravais lattices, reciprocal lattice, diffraction and structure factor; bonding in solids, elastic properties, phonons and lattice specific heat. Free-electron theory, electronic specific heat, response and relaxation phenomena; Drude model, electrical and thermal conductivity, Hall effect and thermoelectric power. Electron motion in periodic potentials; band theory of metals, insulators and semiconductors; superconductivity, Type-I and Type-II superconductors, Josephson junctions and superfluidity. Defects and dislocations; ordered phases of matter, liquid crystalline order and quasicrystals.

UNIT IX: NUCLEAR AND PARTICLE PHYSICS

Basic nuclear properties, binding energy, semi-empirical mass formula, liquid-drop model, nuclear forces and nucleon–nucleon potential; charge independence, charge symmetry and deuteron problem. Nuclear shell model, rotational spectra, alpha, beta and gamma decays, selection rules; fission, fusion and nuclear reactions, including compound and direct reactions. Fundamental forces, elementary particles and quantum numbers; isospin, strangeness, Gell-Mann–Nishijima formula, quark model, baryons and mesons, P and T invariance, symmetry arguments in particle reactions, parity non-conservation in weak interactions and relativistic kinematics.