DEPARTMENT OF PHYSICS
KURUKSHETRA UNIVERSITY, KURUKSHETRA

Syllabus for Ph. D. Entrance Test

I. Mathematical Methods of Physics

Matrices: Orthogonal, Unitary and Hermitian Matrices with examples, Matrix diagonalization, eigen values & eigen vectors.

Group Theory: Definition, Group multiplication table, rearrangement theorem, cyclic groups, sub-groups and cosets, permutation groups, conjugate elements and class structure, normal devisors and factor groups, isomorphism and homomorphism, class multiplication, Groups representation by matrices, reducible and irreducible representations, great orthogonality theorem and its geometric interpretation, character of a representation, construction of character table. The elements of the group of Schrodinger equation.

Special Functions: Bessel Functions Legendre Polynomials, Hermite and Leguerre Polynomials: generating function & recurrence relations and special properties.

Complex variable: Cauchy Riemann conditions, Cauchy's intergral theorem, Cauchy's integral formula, Taylor's and Laurent series, Cauchy's Residue theorem, Singular points and evaluation of residues, Jordan's Lemma. Evaluation of definite integrals.

II. Classical Mechanics

Newton's laws; Phase space dynamics, stability analysis; Central-force motion; Two-body collisions, scattering in laboratory and centre-of-mass frames; Rigid body dynamics, moment of inertia tensor, non-inertial frames and pseudoforces; Variational principle, Lagrangian and Hamiltonian formalisms and equations of motion; Poisson brackets and canonical transformations; Symmetry, invariance and conservation laws, cyclic coordinates; Periodic motion, small oscillations and normal modes; Special theory of relativity, Lorentz transformations, relativistic kinematics and mass–energy equivalence.

III. Electrodynamics

Electrostatics: Gauss' 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 fields at interfaces; Scalar and vector potentials; Gauge invariance; Electromagnetic waves in free space, dielectrics, and conductors; Reflection and refraction, polarization, Fresnel's Law, interference, coherence, and diffraction; Dispersion relations in plasma; Lorentz invariance of Maxwell's equations; Transmission lines and wave guides; Dynamics of charged particles in static and uniform electromagnetic fields; Radiation from moving charges, dipoles and retarded potentials.

IV. Quantum Mechanics

Wave-particle duality; Wave functions in coordinate and momentum representations; Commutators and Heisenberg's uncertainty principle; Matrix representation; Dirac's bra and ket notation; Schrödinger equation (time-dependent and time-independent); Eigenvalue problems such as particle-in-a-box, harmonic oscillator, etc.; Tunneling through a barrier; Motion in a central potential; Orbital angular momentum, Angular momentum algebra, spin; Addition of angular momenta; Hydrogen atom, spin-orbit coupling, fine structure; Time independent perturbation theory and applications; Variational method; WKB approximation; Time dependent perturbation theory and Fermi's Golden Rule; Semi-classical theory of radiation; Elementary theory of scattering, phase shifts, partial waves, Born approximation; Identical particles, Pauli's

exclusion principle, spin-statistics connection; Relativistic quantum mechanics: Klein Gordon and Dirac equations.

V. Thermodynamic and Statistical Physics

Laws of thermodynamics and their consequences; Thermodynamic potentials, Maxwell relations; Chemical potential, phase equilibria; Phase space, micro- and macrostates; Microcanonical, canonical and grand-canonical ensembles and partition functions; Cluster expansion method for a classical gas, Simple cluster integrals, Mayer-Ursell relations, Virial expansion of the equation of state, Van der Waal's equation, Free Energy and connection with thermodynamic quantities; First- and second-order phase transitions; Classical and quantum statistics, ideal Fermi and Bose gases; Blackbody radiation and Planck's distribution law; Bose-Einstein condensation; Brownian motion; Introduction to nonequilibrium processes; Diffusion equation, Ising model in the Bragg-William approximation, Critical exponents, Auto-correlation function and its properties, Fokker-Planck equation.

VI. Electronics

Semiconductor device physics, including diodes, junctions, transistors, field effect devices, homo and heterojunction devices, device structure, device characteristics, frequency dependence and applications; Optoelectronic devices, photodetectors, and LEDs; High-frequency devices, including generators and detectors; 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.

VII. Atomic & Molecular Physics

Quantum states of an electron in an atom; Electron spin; Stern-Gerlach experiment; Spectrum of Hydrogen, helium and alkali atoms; Relativistic corrections for energy levels of hydrogen; Hyperfine structure and isotopic shift; width of spectral lines; LS & JJ coupling; Zeeman, Paschen Back & Stark effect; X-ray, XPS spectroscopy; Electron spin resonance, Nuclear magnetic resonance, chemical shift; Rotational, vibrational, electronic, and Raman spectra of diatomic molecules; Frank – Condon principle and selection rules; Spontaneous and stimulated emission. Einstein A & B coefficients; Lasers, optical pumping, population inversion, rate equation; Modes of resonators and coherence length.

VIII. 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; Drude model of electrical and thermal conductivity; Hall effect; Diamagnetism, paramagnetism, and ferromagnetism; Electron motion in a periodic potential, band theory of metals, insulators and semiconductors; Tight Binding and Wigner-Seitz methods og energy bands; Superconductivity, type – I and type - II superconductors, BCS theory of superconductivity, Josephson junctions; Defects and dislocations; Ordered phases of matter, translational and orientational order, kinds of liquid crystalline order.

IX. Nuclear and Particle Physics

Basic nuclear properties: size, shape, charge distribution, spin and parity; Binding energy, semi-empirical mass formula; Liquid drop model; Fission and fusion; Nature of the nuclear force, form of nucleon-nucleon potential; Charge-independence and charge-symmetry of nuclear forces; Isospin; Evidence of shell structure, single- particle shell model, its validity and limitations; Elementary ideas of alpha, beta and gamma decays; Nuclear reactions, reaction

mechanisms, compound nuclei and direct reactions; Interaction of Charge particles and electromagnetic radiation with matter, Radiation detectors: G. M. Counter, Scintillation,Semiconductor and Solid state nuclear track detectors; Classification of fundamental forces; Elementary particles (quarks, baryons, mesons, leptons); isospin, strangeness; Gell-MannNishijima formula; parity operation on neutrino states.