Department of Physics
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Syllabus for Ph. D. (Physics) Entrance Test 2024

Part A: Research Methodology (50% weightage)

Research: Meaning, objectives, types, approaches. Criteria of good research, research problems, research design. Review of literature: objectives and procedure. Writing report.Quantitative methods of research: Methods of data collection – experimental data, field data, data from secondary sources. Relation between variables: correlation (both continuous & binary data), regression (both linear & non-linear) for two variables. Normal distribution and its application in Physics. Elements of computer programming. Essentials of writing scientific article.

Part B: Physics (50% weightage)

Group A (Multiple choice type questions)

I. Mathematical Physics

Vector algebra and vector calculus. Linear algebra, matrices, Cayley-Hamilton Theorem. Eigenvalues and eigenvectors. Linear ordinary differential equations of first & second order, Special functions (Bessel and Legendre functions). Fourier series, Fourier and Laplace transform. Elements of complex analysis, analytic functions; poles, residues, and evaluation of integrals.

II. 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 moment of inertia tensor. Non-inertial frames and pseudoforces. Variational principle. Generalized coordinates. Lagrangian and Hamiltonian formalism and equations of motion. Conservation laws and cyclic coordinates. Periodic motion: small oscillations, normal modes. Special theory of relativity. Lorentz transformations, relativistic kinematics and mass–energy equivalence.

III. 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. 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. Dynamics of charged particles in static and uniform electromagnetic fields. Relativistic Electrodynamics: Lorentz transformations of fields, Covariant formulation of Maxwell's equations, Field tensors and energy-momentum tensor

IV. 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.

V. Thermodynamics and Statistical Physics

Basic thermodynamics; Thermodynamic parameters and their relations; Microcanonical, Canonical and Grand canonical ensembles; MB, BE and FD distribution functions

VI. Electronics

Semiconductor devices like diodes, bipolar junction transistors (BJTs), and field-effect transistors (FETs), exploring their characteristics, operation principles, and biasing techniques; Optoelectronics and high frequency devices like solar cell, phototransistor, LED, APD, IMPATT and Gunn diode, exploring their characteristics, operation principles only; rectifier circuits (half-wave, full-wave, bridge), along with power supply design principles, including voltage regulation and filtering. different digital logic families like TTL, CMOS, and ECL, exploring their characteristics; designing digital circuits using logic gates, including adders, subtractors, multiplexers, demultiplexer, encoder, decoders, flip-flops, and counters. amplitude modulation (AM), frequency modulation (FM), and pulse modulation techniques, along with demodulation techniques.

Group B (Short answer type questions)

I. Atomic, Molecular and Laser Physics

Hydrogen line spectra and fine structure. Hyperfine structure and isotopic shift; width of spectral lines; LS & JJ coupling; Zeeman, Paschen Back & Stark effect; X-ray 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.

II. Nuclear and Particle Physics

Characteristics of Atomic Nucleus. Nature of Nuclear force. Deuteron Problem. Fermi gas model, Liquid drop model, Semi empirical mass formula, Shell model. Nuclear reactions, Cross sections, Resonance scattering and reactions, Compound nucleus. Parity non-conservation. Elementary particles – classification, quantum numbers, conservation laws. Quarks: Colour confinement, quark structures of mesons and baryons. Quantum chromodynamics, gluon distribution, strong coupling constant, asymptotic freedom. Muon: production and decay. Neutrino mass and oscillation.

III. Condensed Matter Physics

Crystal Structure, Crystal lattice, Unit cell, Bravais lattices, Miller indices, Bragg's law, Reciprocal lattice, Crystal binding and crystal Vibration, Quantization of lattice vibrations, Dispersion relations, Elastic properties of Solid, Electron theory, Density of states and Fermi energy, Fermi distribution function, Brillouin zones, Electrical conductivity, Thermal conductivity, Hall effect, Transport Properties, Optical properties, Elasticity of Crystals, Dielectrics, Disordered in Solids, Superconductivity, Magnetism, Liquid Crystals, Nano-structured materials and nano sciences, Band Theory of Solids, and Density Functional Theory (DFT),

IV. Astrophysics

Celestial Mechanics: Kepler's laws, Newton's laws of motion, gravitational interactions. Astrophysical Phenomena: Black holes, neutron stars, supernovae, and gamma-ray bursts. Stellar Structure: Equations of state, hydrostatic equilibrium, energy generation. Stellar Evolution: Life cycles of stars, nucleosynthesis, and end stages (white dwarfs, neutron stars). Big Bang Theory: Expansion of the universe, cosmic microwave background radiation. Dark Matter and Dark Energy: Evidence for dark matter, effects on galaxy formation. Telescopes and Detectors: Types of telescopes (optical, radio, infrared), CCDs and photometry. Spectroscopy: Techniques for analyzing light from astronomical objects. Galaxy Formation and Evolution: Types of galaxies, interactions between galaxies. Active Galactic Nuclei: Quasars, Seyfert galaxies, and their properties.

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