DEPARTMENT OF PHYSICS
FACULTY OF SCIENCE
Syllabus for Ph.D Admissions Test 2022-23 onwards

SECTION-B

MATHEMATICAL PHYSICS

Matrix analysis, Eigen values and Eigen vectors, Cayley-Hamilton theorem. Vector analysis. Second order differential equations. Special functions (Hermite, Bessel, and Legendre functions). Fourier series and Fourier transforms. Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues and evaluation of integrals. Green's function technique. Introductory tensor analysis and group theory.

CLASSICAL MECHANICS

Newton's laws. Central force motions. Two body Collisions - scattering in laboratory and Centre of mass frames. Variational principle. Generalised coordinates. Lagrangian and Hamiltonian formalism and equations of motion. Conservation laws and cyclic coordinates. Special theory of relativity- Lorentz transformations, relativistic kinematics and mass–energy equivalence. Poisson brackets and canonical transformations. Symmetry, invariance and Noether's theorem.

ELECTROMAGNETIC THEORY

Electrostatics: Gauss's law, Laplace and Poisson equations, boundary value problems. Magneto-statics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations. Scalar and vector potentials, gauge invariance. Electromagnetic waves in free space. Dielectrics and conductors. Dynamics of charged particles in static and uniform electromagnetic fields. Lorentz invariance of Maxwell's equation. Transmission lines and wave guides.

QUANTUM MECHANICS

Wave-particle duality. Schrödinger equation. Particle in a box, harmonic oscillator, tunnelling through a barrier. Commutators and Heisenberg uncertainty principle. Motion in a central potential: orbital angular momentum and spin; hydrogen atom. Perturbation theory. Elementary theory of scattering. Relativistic quantum mechanics: Klein-Gordon and Dirac equations. Quantisation of Klein-Gordon, Dirac field and electromagnetic fields.

THERMODYNAMICS AND STATISTICAL PHYSICS

Laws of thermodynamics. Thermodynamic potentials, Maxwell relations. Phase space, micro- and macro-states. Micro-canonical, canonical, grand-canonical ensembles and partition functions. Free energy. Classical and quantum statistics. Ideal Bose and Fermi gases. Blackbody radiation and Planck's distribution law. Ising model. Bose-Einstein condensation. Random walk and Brownian motion. Introduction to non-equilibrium processes.

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

ATOMIC, MOLECULAR AND LASER PHYSICS

Atomic Spectroscopy: LS and JJ coupling schemes. Terms for equivalent and non-equivalent electron atom. Spectra of one system. Electron spin, spin orbit interaction, fine structure, relativistic correction and radiation correction (Lamb Shift). Electric dipole selection rules. Intensity rules. Alkali type spectra. Zeeman effect. Paschen-Back effect. Stark effect. Hyperfine structure and isotopic shifts. X-rays and Auger transitions.

Molecular Spectroscopy: Rotational spectra of diatomic molecules. Vibrational spectra of diatomic molecules. Rotation-vibration spectra of diatomic molecules. Classification of electronic states. Electronic spectra of diatomic molecules. Hund's cases. Vibrational structure of electronic transition. Selection rules. Rotational fine structure. Franck-Condon principle. Intensity of bands in absorption and emission. Isotopic shift. Infrared and Raman spectra of linear molecules. Nuclear Magnetic Resonance (NMR), Electron Spin Resonance (ESR).

Laser Physics: Einstein coefficients, Trasition propability and lifetime of an atom in an excited state line broadening mechanisms. Population inversion. Laser rate equations: The three level and four level systems. Optical resonators: Quality factor, Threshold conditions. Laser Systems: He-Ne laser. CO_2 laser. Four level solid state lasers. Dye lasers. Ar+ laser. Excimer lasers. Properties of laser beam: directionality, monochromacity, intensity, coherence (temporal and Spatial). Applications of lasers: Laser induced fusion. Isotope separation.

CONDENSED MATTER PHYSICS

Lattice translation vectors, Miller indices, symmetry operations and space groups; common crystals; Bonding in solids.
Reciprocal lattice, diffraction and structure factor; Brillouin zones; diffraction of x-rays by crystals, Bragg's law, Bragg formulation, Laue formulation, structure factor of bcc, fcc, diamond and hcp structures.

Lattice vibrations: linear monatomic and diatomic chains, acoustical and optical phonons, adiabatic approximation, normal modes of real crystals, dispersion curve; Dulong and Petit's law, Einstein and Debye theories of specific heat of solids, T^3 law.
Free electron theory: Drude model of electrical and thermal conductivity, Sommerfeld model of free election gas, Boltzmann transport equation, d.c. conductivity, Hall effect; defects and imperfections; colour centres.

Energy bands: Failure of free electron model, Bloch's Theorem, Nearly free electron model, Semiconductors: equations of motion of charge carriers in electric and magnetic fields, effective mass, intrinsic and extrinsic conductivity, law of mass action.
Alloys, order-disorder transformation, elementary theory of order, Kondo effect. Plasmons, plasma oscillations.

Pyroelectricity and ferroelectricity: Polarization catastrophe, soft modes; first and second-order phase transitions, piezoelectric crystals, applications.

Magnetism: quantum theory of diamagnetism and paramagnetism, van vleckparamagnetism, Pauli paramagnetism, Neel model of antiferromagnetism and ferrimagnetism; spin waves, magnons in ferromagnets; Bloch $T^{3/2}$ law; magnons in antiferromagnets, temperature dependence of spontaneous magnetization; exchange interaction (two electron system), Heisenberg model (spin Hamiltonian); ferromagnetic domains.

Superconductivity: Meissner effect, London equations, Type I & type II superconductors, Isotope effect, BCS theory; thermodynamic properties, flux quantization, Giaever tunneling, ac and dc Josephson effects, supercurrent quantum interference, high temperature superconductors, applications of superconductors.

NUCLEAR PHYSICS

Constituents of nucleus and their intrinsic properties, nuclear mass: measurement of mass using mass spectrograph, defect, binding energy. Idea of nuclear fusion-fission, nuclear angular momentum, nuclear magnetic dipole moment, nuclear quadrupole moment.

Alpha decay; energetics of α-decay, Geizer-Nuttal Law, Gamow theory of α-decay. Beta decay: Neutrino hypothesis, Fermi theory of β-decay, Fermi-Kurie plot, comparative half-life. Selection rules: allowed and forbidden transitions, Idea of electron capture, Gamma decay: energetics of γ-decay, Multipole radiations, selection rules, Idea of Internal Conversions of γ-rays and Coulomb excitation.

Radioactive series decay, types of nuclear reactions, conservation laws, Q-value: threshold energy, Energetics of nuclear reactions, energetics of α, β^+, β^- and electron capture (EC) decay. Standard Q-equation and its solution, nuclear reaction, cross-section, idea of differential cross-section, compound reaction mechanism and its verification – Ghoshal's experiment, Idea of pre-compound emission, direct reactions and their signatures. Liquid drop model; Weizsacker's semi-emperical mass formula and some of its applications.

Energy loss due to ionization (Bethe block formula), range and straggling, Cerenkov radiation, Interaction of Gamma radiation with matter, Photoelectric effect, Compton scattering, Pair production. Detectors for Nuclear radiations: Gas filled detectors, G. M. Counter, Basic principle of Scintillation detectors, Cherenkov counter and construction of Photo multiplier tube (PMT). Principle of Semiconductor detectors. Position sensitive gas filled detectors.

Berit-Winger one level formula.

The ground state of the deuterons: Ground state of the deuteron and D-state admixture, Magnetic and electric quadrupole moments. Electromagnetics properties of nuclei: Transitions probabilities, electric and magnetic multipole moments

Physical description of heavy ion interaction, nuclear rainbow scattering, exotic and super heavy nuclei.

PARTICLE PHYSICS

Basic interactions and their mediationg quanta, classification of particles: Fermions, Bosons and leptons and hadrons, particles and anti particles, idea of resonances, conservation rules in fundamental interactions, determination of spin and parity of pions, strange particles , isospin and its conservation, quarks and their quantum numbers and quark model.

Space reflection and parity, parity of charged pion, parity non-conservation in β-decay, charge conjugation, time reversal, CPT theorem, and symmetry and conservation rules.
Neutrino flavours, mass limits, neutrino detection helicity of neutrino, energy of neutrino for pion decay in flight and decay at rest, difference between ν and $\bar{\nu}$ and ν_e and ν_μ and neutrino flavour oscillations.
Introduction to Spin ½ and Spin 3/2 resonances, quark flavours, confinement. Baryon decuplet and octet.Colour degree of freedom. Magnetic moments of baryons, Mass relations and splittings. Mesons built of light and heavy quarks.

Weak, electromagnetic and strong decays of particles,, weak decays of strange particles and Cabbibo theory. Decay rates for $\pi^- \rightarrow \mu^- \nu_\mu(\bar{\nu}_\mu)$ and $\pi^- \rightarrow e^- \nu_e(\bar{\nu}_e)$ processes.
Natural units, Lorentz transformations for energy and momentum, four-vectors and invariants, Laboratory and Centre-of-momentum systems, calculation of energy, momentum and angle of particles produced in nuclear reactions in Lab. and centre-of-momentum frames and their transformations, two body decay at rest and calculation of threshold energies for particle production.
Phenomenology of strange particles and their semileptonic and nonleptonic decays.Cabibbo theory. Neutral kaon decays and CP violation. Flavour oscillation.