New Proposed Syllabus – CSIR NET Physical Science

PHYSICAL SCIENCES

Part B (Core)

1. Mathematical Methods of Physics

Dimensional analysis. Vector algebra and vector calculus. Linear algebra, matrices, Cayley-Hamilton Theorem. Eigenvalues and eigenvectors. Linear ordinary differential equations of first and second order. Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions. Structure of singularities: poles and branch points, essential singularity. Taylor and Laurent series. Residues and evaluation of integrals. Elementary probability theory, random variables, binomial, Poisson, and normal distributions. Central limit theorem. Elements of computational techniques: root of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule, Solution of first-order differential equation eg, using the Runge-Kutta method. Finite difference methods.

II. Classical Mechanics

Newton's laws. Two-body problems. Motion in a central force field. Scattering in laboratory and centre of mass frames, two-body collision. Dynamics of rigid bodies. Moment of inertia tensor. Non-inertial frames and pseudo-forces. Principles of least action. Generalized coordinates and velocities. Lagrangian, Euler-Lagrange equations. Legendre transformation, generalized momenta, Hamiltonian, and Hamilton's equations of motion. Conservation laws and cyclic coordinates. Periodic motion, small oscillations. Normal modes. Special theory of relativity: Lorentz transformations, relativistic kinematics, and equivalence of mass and energy.

III. Electromagnetic Theory

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 in linear isotropic media, boundary conditions on the fields at interfaces of media. Scalar and vector potentials, gauge invariance, gauge fixing. Electromagnetic waves in free space. Polarization. Dielectrics and conductors. Reflection and refraction of electromagnetic waves, total internal reflection. Interference, coherence, and diffraction of electromagnetic waves. Young's double-slit experiment. Dynamics of charged particles in static and uniform electromagnetic fields.

IV. Quantum Mechanics

Planck hypothesis. Photoelectric effect. Bohr-Sommerfeld quantization. De Broglie's matter wave. Time evolution of a quantum system, Schrödinger equation, unitary evolution operator. Eigenvalue problem (time-independent Schrödinger equation), examples in one, two, and three dimensions, bound states (particle in a box, simple harmonic oscillator, etc.). Wavefunctions and their coordinate and momentum representations. Reflection and transmission in one dimension. Tunnelling through a barrier. Schrödinger and Heisenberg pictures. Equal time commutators of operators, Heisenberg uncertainty relations, Dirac notation for state vectors and operators. Orbital angular momentum. Angular momentum algebra and its representation. Spin, Stern-Gerlach experiment. Addition of angular momenta, Clebsch-Gordon coefficients. Wigner-Eckart theorem. Motion in a central potential, bound states of the hydrogen atom. Identical particles, bosons and fermions. Pauli exclusion principle.

V. Thermodynamic and Statistical Physics

Laws of thermodynamics and their applications (ideal gas, magnetic systems, dielectric materials, etc. Extensive and intensive variables). Thermodynamic potentials, Maxwell relations, chemical potential, and phase equilibria. Phase space, micro- and macro-states. Liouville's theorem. Ensembles: microcanonical, canonical, and grand canonical ensembles. Partition functions, free energies, and their connection with thermodynamic quantities. Probability distributions (binomial, Poisson, Gaussian). Random walk. Central limit theorem. Statistical mechanics of discrete (e.g., Ising) and continuous (e.g., ideal gas) systems. Classical statistics, Maxwell-Boltzmann distributions. Quantum statistics, Bose and Fermi systems. Debye theory of specific heat. Black-body radiation and Planck's distribution law. Simple metals.

VI. Electronics and Experimental Methods

Semiconductor devices (diodes, junctions, transistors, field effect devices, homo- and hetero-junction devices), device structure, device characteristics, frequency dependence. Opto-electronic devices (solar cells, photo-detectors, LED). Applications of devices. Operational amplifiers and their applications. Digital techniques and their applications (registers, counters, comparators, and similar circuits). A/D and D/A converters. Microprocessors and microcontroller basics. Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). Interpretation and analysis of data. Precision and accuracy. Error analysis, propagation of errors. Curve fitting by the least squares method. Chi-square test.

Part C (Advanced)

1. Mathematical Methods of Physics

(The following are in addition to all the topics in Part B.)

Green's function. Partial differential equations: Laplace, wave, and heat equations in two and three dimensions. Special functions (Hermite, Bessel, Legendre, and Laguerre functions). Tensors. Elements of group theory, finite groups. Continuous groups: O(3) and SU(2).

II. Classical Mechanics

(The following are in addition to all the topics in Part B.)

Dynamical systems, Phase space dynamics, stability analysis. Poisson brackets and canonical transformations. Symmetry, invariance, and Noether's theorem. Hamilton-Jacobi theory.

III. Electromagnetic Theory

(The following are in addition to all the topics in Part B.)

Dispersion relations in plasma. Lorentz covariance of Maxwell's equation. Transmission lines and wave guides. Radiation from moving charges and dipoles, retarded potentials.

IV. Quantum Mechanics

(The following are in addition to all the topics in Part B.)

Time-independent perturbation theory and applications. Variational method. WKB approximation. Time-dependent perturbation theory: interaction picture, constant and harmonic perturbations, Fermi's golden rules, selection rules. Sudden and adiabatic approximations. Scattering in three dimensions: Born approximation, partial waves, phase shifts. Mixed states, density matrix. Relativistic quantum mechanics: Klein-Gordon and Dirac equations.

V. Thermodynamic and Statistical Physics

(The following are in addition to all the topics in Part B.)

Thermodynamics of first- and second-order phase transitions. Metastable states, coexistence of phases. Landau theory. Spontaneous symmetry breaking. Critical phenomena at second-order phase transitions, critical exponents. Phenomenology of dia-, para-, and ferro- and anti-ferromagnetism. Ising model. Bose-Einstein condensation. Superfluidity and superconductivity. Diffusion equation. Brownian motion. Linear response theory.

VI. Electronics and Experimental Methods

(The following are in addition to all the topics in Part B.)

Measurement and control. Signal conditioning and recovery. Impedance matching, amplification (op-amp based, instrumentation amp, feedback), oscillators, filtering and noise reduction, shielding and grounding. Fourier transforms, lock-in detector, box-car integrator, modulation techniques. Low temperature measurement techniques. High-frequency devices (including generators and detectors).

VII. Atomic and Molecular Physics

Quantum states of an electron in an atom. Effects due to the spin of electrons. Hund's rule. Spectrum of helium and alkali atoms. Periodic table, physical and chemical properties of atoms. Relativistic corrections and fine structure of hydrogenic atoms. Hyperfine structure and isotopic shift. LS and JJ coupling. Term symbols. Zeeman, Paschen-Bach, and Stark effects. Electron spin resonance. Nuclear magnetic resonance, chemical shift. Hydrogen molecular ion and hydrogen molecule, Molecular orbitals. Born-Oppenheimer approximation.

Bonds: Electronic, rotational, vibrational, and Raman spectra of diatomic molecules, selection rules. Frank-Condon principle. Spectral broadening and line width. Atoms in an electromagnetic field. Absorption, spontaneous and stimulated emissions. Einstein A and B coefficients.

Lasers: optical pumping, population inversion, rate equation. Atom cooling and trapping.

VIII. Condensed Matter Physics

Bravais lattice and classification of Bravais lattices in two and three dimensions. Reciprocal lattice. Brillouin zone. Diffraction and structure factor. Types of bonding of solids.

Elastic properties. Phonons, lattice-specific heat. Free electron theory and electronic specific heat. Response and relaxation phenomena. Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Electron motion in a periodic potential, Bloch's theorem. Band theory of solids, Fermi surface, metals, insulators, and semiconductors.

Superconductivity: type-I and type-II superconductors. Cooper pairs. DC and AC Josephson effect. Superfluidity. Translational and orientational order. Liquid crystals.

IX. Nuclear and Particle Physics

Properties of nuclei: size, shape, and charge distribution, spin, and parity. Binding energy. Semi-empirical mass formula, liquid drop model. Single-particle shell model, magic number. Application to the properties of low-lying states, electric quadrupole and magnetic dipole moments. Nature of nuclear force, nucleon-nucleon potential, charge independence, and spin dependence of nuclear forces. Deuteron. Collective motion of nuclei: vibration and rotation.

Alpha, beta, and gamma decays and their selection rules. Parity non-conservation in weak interaction, Wu's experiment. Fission. Nuclear reactions. Fusion, energy generation in the Sun. Accelerators: tandem and linear accelerators, cyclotron and synchrotron. Detectors: bubble and cloud chambers, proportional counters, scintillators, semiconductor-based detectors, etc.

Classification of fundamental forces. Elementary particles and their quantum numbers: charge, spin, parity, isospin, strangeness, etc. Gellmann-Nishijima formula. Quark model, baryons and mesons. Flavour and colour. Constituents of the Standard Model of particle physics: quarks, leptons, gauge bosons, and the Higgs. Application of symmetry arguments to the interaction of particles. P, C, and T invariance.