

## PHYSICS

### I. **Basic Mathematical Methods of Physics:**

Dimensional analysis; Vector algebra and vector calculus; Linear algebra, matrices, Cayley Hamilton theorem, eigenvalue problems; Linear differential equations; Special functions (Hermite, Bessel, Laguerre and Legendre); Fourier series, Fourier and Laplace transforms; Elements of complex analysis: Laurent series-poles, residues and evaluation of integrals; Elementary ideas about tensors; Introductory group theory,  $SU(2)$ ,  $O(3)$ ; Elements of computational techniques: roots of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule, solution of first order differential equations using Runge - Kutta method; Finite difference methods; Elementary probability theory, random variables, binomial, Poisson and normal distributions.

### 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. **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 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; Schroedinger equation (time-dependent and time-independent); Eigenvalue problems such as particle-in-a-box, harmonic oscillator, etc.; Tunnelling 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; Selection rules; 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. **Thermodynamics 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; Free Energy and connection with thermodynamic quantities; First- and second-order phase transitions; Classical and quantum statistics, ideal Fermi and Bose gases; Principle of

detailed balance; Blackbody radiation and Planck's distribution law; Bose-Einstein condensation; Einstein and Debye models for lattice specific heat. Random walk and Brownian motion; Introduction to non-equilibrium processes; Diffusion equation.

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#### **VI. Electronics and Experimental Methods:**

Semiconductor devices (diodes, transistors, field effect 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 micro controller basics. Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least squares fitting, Linear and nonlinear curve fitting, chi-square test. Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). Basics of signals and communication.

#### **VII. Atomic & Molecular Physics:**

Quantum states of an electron in an atom. Electron spin. Spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectral lines, LS & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Electron spin resonance. Nuclear magnetic resonance, chemical shift. Frank-Condon principle. Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Lasers: spontaneous and stimulated emission, Einstein A & B coefficients. Optical pumping, population inversion, rate equation. Modes of resonators and coherence length. Ruby and He-Ne laser.

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### **VIII. Condensed Matter Physics**

Bravais lattices; reciprocal lattice, diffraction and the structure factor. Defects and dislocations. Bonding of solids. Elastic properties, phonons, lattice specific heat. Free electron theory of metals. Drude model of electrical and thermal conductivity. Fermi statistics, electronic specific heat. Response and relaxation phenomena. Hall effect in metals and semi conductors, thermo electric power. Electron motion in a periodic potential, band theory of solids: metals, insulators and semiconductors. Superconductivity: type-I and type-II superconductors. Meissner effect, thermodynamic properties-heat capacity-thermal conductivity Josephson junctions, BCS theory, super fluidity. Liquid crystalline order types and quasi crystals.

### **IX. Nuclear and Particle Physics**

Basic nuclear properties: size, shape and charge distribution, spin and parity. Binding energy, semi-empirical mass formula, liquid drop model. Nature of the nuclear force, form of nucleon-nucleon potential, charge-independence and charge-symmetry of nuclear forces. Deuteron problem. Evidence of shell structure, single-particle shell model, its validity and limitations. Elementary ideas of alpha, beta and gamma decays and their selection rules. Fission and fusion. Nuclear reactions, reaction mechanism, compound nuclei and direct reactions. Classification of fundamental forces. Elementary particles (quarks, baryons, mesons, leptons )and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellmann - Nishijima formula. Quark model, baryons and mesons. C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction. Relativistic kinematic.

## **X. Nano Science:**

Classification, electron confinement, size effect, bulk materials, distinct properties of Nano materials, Quantum dots, Nano wires, Carbon Nano cones, Nanofilms, multi-layered materials, Fullerenes, Carbon Nanotubes (CNT), Carbon Nano cones, Hackelites, Graphene, Synthesis techniques, Characterization techniques, Production methods for CNT, Mechanical and Electrical properties of CNT, Nano material advantages. Applications to fuel cells, phosphors, computer chips, sensors