

### **1. 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. Reflection and refraction, polarization, Fresnel's law, interference, coherence, and diffraction. Dynamics of charged particles in static and uniform electromagnetic fields.

### **2. Quantum Mechanics**

Wave-particle duality, de-Broglie hypothesis, Davisson Germer experiment. Schrödinger equation (time-dependent and time-independent). Eigenvalue problems (particle in a box and harmonic oscillator). Tunnelling through a barrier. Wave-function in coordinate and momentum representations. Commutators and Heisenberg uncertainty principle. 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.

### **3. Statistical Mechanics**

Laws of thermodynamics and their consequences. Thermodynamic potentials, Maxwell relations, chemical potential, phase equilibria. Phase space, micro- and macro-states. Micro-canonical, canonical and grand-canonical ensembles and partition functions. Free energy and its connection with thermodynamic quantities. Classical and quantum statistics. Ideal Bose and Fermi gases. Principle of detailed balance. Blackbody radiation and Planck's distribution law.

### **4. Atomic and 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 spectrum lines, LS & JJ couplings. Zeeman and Paschen-Bach effects. Frank - Condon principle. Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Lasers: spontaneous and stimulated emission, Einstein's A & B coefficients. Requisites of laser, CO<sub>2</sub> and diode laser.

## **5. 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. Response and relaxation phenomena. Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Electron motion in a periodic potential, band theory of solids: metals, insulators and semiconductors. Superconductivity: BCS theory, type-I and type-II superconductors. Josephson junctions. Defects and dislocations. Dielectric materials: Polarisation mechanisms, Lorentz field, Clausius-Mosotti equation, dielectric loss and breakdown, frequency and temperature dependence of dielectric properties.

## **6. Nuclear 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. Evidence of shell structure, single-particle shell model, its validity and limitations. Particle accelerators: Cyclotron, Synchrotron and synchrocyclotron. Nuclear detectors: Ionisation chamber and solid state detector. Nuclear fusion and fission reactions.