

Physics

Paper-I

Section A

1. Classical Mechanics:

1.1. Particle dynamics: Centre of mass and laboratory coordinates, conservation of linear and angular momentum. The rocket equation. Rutherford scattering, Galilean transformation, inertial and non-inertial frames, rotating frames, centrifugal and Coriolis forces, Foucault pendulum.

1.2. System of particles: Constraints, degrees of freedom, generalised coordinates and momenta. Lagrange's equation and applications to linear harmonic oscillator, simple pendulum and central force problems. Cyclic coordinates, Hamiltonian Lagrange's equation from Hamilton's principle.

1.3. Rigid body dynamics: Eulerian angles, inertia tensor, principal moments of inertia. Euler's equation of motion of a rigid body, force-free motion of a rigid body. Gyroscope.

2. Special Relativity, Waves & Geometrical Optics:

2.1. Special Relativity: Michelson-Morley experiment and its implications. Lorentz transformations-length contraction, time dilation, addition of velocities, aberration and Doppler effect, mass-energy relation, simple applications to a decay process. Minkowski diagram, four dimensional momentum vector. Covariance of equations of physics.

2.2. Waves: Simple harmonic motion, damped oscillation, forced oscillation and resonance. Beats. Stationary waves in a string. Pulses and wave packets. Phase and group velocities. Reflection and Refraction from Huygens' principle.

2.3. Geometrical Optics: Laws of reflection and refraction from Fermat's principle. Matrix method in paraxial optic-thin lens formula, nodal planes, system of two thin lenses, chromatic and spherical aberrations.

3. Physical Optics:

3.1. Interference: Interference of light-Young's experiment, Newton's rings, interference by thin films, Michelson interferometer. Multiple beam interference and Fabry-Perot interferometer. Holography and simple applications.

3.2. Diffraction: Fraunhofer diffraction-single slit, double slit, diffraction grating, resolving power. Fresnel diffraction: - half-period zones and zones plates. Fresnel integrals. Application of Cornu's spiral to the analysis of diffraction at a straight edge and by a long narrow slit. Diffraction by a circular aperture and the Airy pattern.

3.3. Polarisation and Modern Optics: Production and detection of linearly and circularly polarised light. Double refraction, quarter wave plate. Optical activity. Principles of fibre optics attenuation; pulse dispersion in step index and parabolic index fibres; material dispersion, single mode fibres. Lasers-Einstein A and B coefficients. Ruby and He-Ne lasers. Characteristics of laser light-spatial and temporal coherence. Focussing of laser beams. Three-level scheme for laser operation.

Paper-I

Section B

1. Electricity and Magnetism:

1.1 Electrostatics and Magnetostatics: Laplace and Poisson equations in electrostatics and their applications. Energy of a system of charges, multipole expansion of scalar potential. Method of images and its applications. Potential and field due to a dipole, force and torque on a dipole in an external field. Dielectrics, polarisation. Solutions to boundary-value problems-conducting and dielectric spheres in a uniform electric field. Magnetic shell, uniformly magnetised sphere. Ferromagnetic materials, hysteresis, energy loss.

1.2. Current Electricity: Kirchhoff's laws and their applications. Biot-Savart law, Ampere's law, Faraday's law, Lenz' law. Self-and mutual-inductances. Mean and rms values in AC circuits. LR CR and LCR circuits- series and parallel resonance. Quality factor. Principle of transformer.

2. Electromagnetic Theory & Black Body Radiation:

2.1. Electromagnetic Theory: Displacement current and Maxwell's equations. Wave equations in vacuum, Poynting theorem. Vector and scalar potentials. Gauge invariance, Lorentz and Coulomb gauges. Electromagnetic field tensor, covariance of Maxwell's equations. Wave equations in isotropic dielectrics, reflection and refraction at the boundary of two dielectrics. Fresnel's relations. Normal and anomalous dispersion. Rayleigh scattering.

2.2. Blackbody radiation: Black body radiation and Planck radiation law- Stefan-Boltzmann law, Wien displacement law and Rayleigh-Jeans law. Planck mass, Planck length, Planck time, Planck temperature and Planck energy.

3. Thermal and Statistical Physics:

3.1. Thermodynamics: Laws of thermodynamics, reversible and irreversible processes, entropy. Isothermal, adiabatic, isobaric, isochoric processes and entropy change. Otto and Diesel engines, Gibbs' phase rule and chemical potential. van der Waals equation of state of a real gas, critical constants. Maxwell-Boltzmann distribution of molecular velocities, transport phenomena, equipartition and virial theorems. Dulong-Petit, Einstein, and Debye's theories of specific heat of solids. Maxwell's relations and applications. Clausius- Clapeyron equation. Adiabatic demagnetisation, Joule-Kelvin effect and liquefaction of gases.

3.2. Statistical Physics: Saha ionization formula. Bose-Einstein condensation. Thermodynamic behaviour of an ideal Fermi gas, Chandrasekhar limit, elementary ideas about neutron stars and pulsars. Brownian motion as a random walk, diffusion process. Concept of negative temperatures.

Paper-II Section A

1. Quantum Mechanics I:

Wave-particle duality. Schrodinger equation and expectation values. Uncertainty principle. Solutions of the one-dimensional Schrodinger equation free particle (Gaussian wave-packet), particle in a box, particle in a finite well, linear harmonic oscillator. Reflection and transmission by a potential step and by a rectangular barrier. Use of WKB formula for the life-time calculation in the alpha-decay problem.

2. Quantum Mechanics II & Atomic Physics:

2.1. Quantum Mechanics II: Particle in a three dimensional box, density of states, free electron theory of metals. The angular momentum problem. The hydrogen atom. The spin half problem and properties of Pauli spin matrices.

2.2. Atomic Physics: Stern-Gerlach experiment, electron spin, fine structure of hydrogen atom. L-S coupling, J-J coupling. Spectroscopic notation of atomic states. Zeeman effect. Frank-Condon principle and applications.

3. Molecular Physics:

Elementary theory of rotational, vibrational and electronic spectra of diatomic molecules. Raman effect and molecular structure. Laser Raman spectroscopy Importance of neutral hydrogen atom, molecular hydrogen and molecular hydrogen ion in astronomy Fluorescence and Phosphorescence. Elementary theory and applications of NMR. Elementary ideas about Lamb shift and its significance.

Paper-II

Section B

1. Nuclear Physics:

Basic nuclear properties-size, binding energy, angular momentum, parity, magnetic moment. Semi-empirical mass formula and applications. Mass parabolas. Ground state of a deuteron magnetic moment and non-central forces. Meson theory of nuclear forces. Salient features of nuclear forces. Shell model of the nucleus-success and limitations. Violation of parity in beta decay. Gamma decay and internal conversion. Elementary ideas about Mossbauer spectroscopy. Q-value of nuclear reactions. Nuclear fission and fusion, energy production in stars. Nuclear reactors.

2. Particle Physics & Solid State Physics:

2.1. Particle Physics: Classification of elementary particles and their interactions. Conservation laws. Quark structure of hadrons. Field quanta of electroweak and strong interactions. Elementary ideas about Unification of Forces. Physics of neutrinos.

2.2. Solid State Physics: Cubic crystal structure. Band theory of solids- conductors, insulators and semiconductors. Elements of superconductivity, Meissner effect, Josephson junctions and applications. Elementary ideas about high temperature superconductivity.

3. Electronics:

Intrinsic and extrinsic semiconductors-p-n-p and n-p-n transistors. Amplifiers and oscillators. Op-amps. FET, JFET and MOSFET. Digital electronics-Boolean identities, De Morgan's laws, Logic gates and truth tables., Simple logic circuits. Thermistors, solar cells. Fundamentals of microprocessors and digital computers.