CSM – 58/21
Physics
Paper – I

Time : 3 hours

Full Marks : 300

The figures in the right-hand margin indicate marks.

Candidates should attempt Q. No. 1 from Section – A and Q. No. 5 from Section – B which are compulsory and any ***three*** *of the remaining questions, selecting at least* ***one*** *from each Section.*

SECTION – A

1. Answer any **three** questions of the following :

   (a) Define scattering cross section. Derive an expression for Rutherford scattering cross section. 20

   (b) Define a rigid body. Derive Euler's equations of motion for a rotating rigid body. 20

(c) State Fermat's principle. Derive the law of refraction using Fermat's principle. 20

(d) How does light propagates in an optical fibre ? Derive an expression for pulse dispersion in a single mode fibre. 20

2. (a) Derive the Lagrangian and the Hamiltonian for a simple pendulum. Derive its Hamilton's equations of motion. 20

(b) From Lorentz transformations deduce the velocity addition law.

If two rockets A and B are moving in the easterly direction with velocities 0.4 C and 0.8 C respectively, what is the velocity of B as observed from A ? Here C denotes the velocity of light. 20

(c) Define the inertia tensor of a rigid body. Obtain the inertia tensor of a uniform rectangular plate rotating about an axis passing through its center and perpendicular to the plane of the plate. 20

3. (a) Define a damped harmonic oscillator having a damping force proportional to velocity. Derive the amplitude of its motion as a function of time. 20

(b) Derive an expression for the frequency of light in relativistic Doppler effect. What is the observed wavelength if a source moving towards us with a velocity of 1.8×10^8 m/s emits a wave length of 580 nm in its rest frame ? 20

(c) What is paraxial approximation ? Derive an expression relating the object distance, image distance and the focal length for a thin lens in the paraxial approximation. 20

4. (a) Give the theory of Fringe formation by a thin film. How can it be used to find wavelengths of different colours ? 20

(b) Explain the working of Zone plates. Work out the radii of the zones for a zone plate using $\lambda = 600$ nm. 20

(c) Explain the working of a three-level laser. How is the coherence time related to the widths of the levels ? 20

SECTION – B

5. Answer any **three** questions of the following :

(a) Explain the method of images for obtaining the potential of a point charge placed in front of an infinite conducting plane. If the value of the charge is 10^{-6} coulomb, find the force it experiences when placed at a distance of 20 cm from a conducting plane. 20

(b) Derive an expression for the quality factor of an LCR circuit. How does it differ for parallel and series circuits ? 20

(c) Define the electromagnetic field tensor. Express Maxwell's equations in terms of the EM field tensor. 20

(d) Derive the Maxwell-Boltzmann distribution law for molecular velocities. Find the mean velocity for molecules at a temperature T. 20

6. (a) Find the electrostatic potential at a general point when a conducting sphere is placed in a uniform electrostatic field. 20

(b) State and prove the Poynting theorem for an electromagnetic field. Hence, find the pressure due to a plane wave of frequency w. 20

(c) Derive Wien's displacement law from the Planck's distribution law for blackbody radiation. Find the peak wavelength for a blackbody radiation at a temperature of 5000 K. 20

7. (a) Define the scalar and vector potentials for an electromagnetic field. Work out the vector potential for a long straight current carrying wire. 20

(b) What is Rayleigh scattering ? Derive an expression for Rayleigh scattering of a monochromatic electromagnetic wave by spherical particles. 20

(c) Deduce the Planck's distribution law for

blackbodies. Calculate the number density of photons in a balckbody at a temperature of 1000 K. 20

8. (a) Derive an expression for the change in entropy of an ideal gas in a closed isobaric process. 20

(b) Derive the specific heat of solids in Einstein's model of solids. 20

(c) What is Gibb's Paradox ? How is it explained for an ideal gas ? 20