

PHYSICS (Paper I)

Time Allowed : Three Hours

Maximum Marks : 300

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.

Candidate has to attempt FIVE questions in all.

Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.

All questions carry equal marks.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. Answer any three of the following:
 - (a) How do we infer the law of conservation of linear momentum from Newton's laws of motion? A stationary bomb explodes and on explosion, it fragments into three parts. Two of these part which are of equal masses fly apart perpendicular to each other with a velocity of 60 m/s each. The third part has a mass four times the other two. Find the magnitude and the direction of the velocity of the third part.
 - (b) A short-focus lens is used to focus a laser beam of wavelength 6328 Å. If the beam width is comparable to the focal length of the lens, calculate the area of cross-section of the region of focus.
 - (c) The specific heat of a substance is found to vary with temperature in the following way
$$c(T) = aT + bT^2$$
where $c(T)$ is the specific heat at the temperature T and 'a' and 'b' are constants. Compare the average specific heat of the substance in the temperature range 0– T to the specific heat at the mid-temperature $T/2$.
 - (d) Prove that the expression $x^2 + y^2 + z^2 - c^2 t^2$ is invariant under Lorentz transformation.
2.
 - (a) Explain the precession of a spinning top and show that precessional angular velocity is independent of the angle of inclination. A top is spinning with 20 rev/s about an axis inclined at 30° with the vertical. Its radius of gyration is 5 cm. The centre of mass is π cm from the pivot point. Calculate the frequency of precession.
 - (b) Starting from the definition of angular momentum of a single particle, obtain an expression for the angular momentum of a rotating rigid body. Hence, discuss the time derivative of the angular momentum and deduce the law of conservation of momentum.
 - (c) Explain the concept of internal energy of a system. Formulate mathematically the first law of thermodynamics. Calculate the work done in an isothermal compression of a gas.
3.
 - (a) Consider the motion of a rocket in a gravitational field and derive an expression for its final velocity when the fuel burns at a constant rate till it is fully consumed.
 - (b) Distinguish between elastic and inelastic collision. Find the minimum distance an α -particle with kinetic energy of 0.4 Mev can approach a stationary but free Lithium nucleus in a head-on collision.
 - (c) Explain why a two-level system is not adequate for laser operation. Draw the essential parts of a ruby laser and explain the working principle with the help of an energy level diagram.

4. (a) At the N.T.P., the mass of one litre of Hydrogen is 0.09 gm. Calculate the (i) RMS (ii) Mean and (iii) Most Probable Speed at 27° C.
- (b) Mention the assumptions made by Einstein in explaining the variation of specific heat of solids with temperature. Show how these assumptions were used to derive the formula for the specific heat of solids. How and why Einstein's theory fails at very low temperatures.
- (c) Discuss the Reynolds number for describing the stability of fluid flow, Air streams horizontally across an aeroplane wing of area 4 m² and weighing 300 kg. The air speed is 60 m/s and 40 m/s over the top surface and under the bottom surface respectively. Find (i) the lift on the wing and (ii) the net force on it, given that the density of air is equal to 1.293 kg/m³.

SECTION 'B'

5. Answer any three of the following
- (a) The equation of a one-dimensional propagating harmonic transverse wave is given by:

$$y=8\sin 30\pi(t-x/240) \text{ meter}$$
Find the resultant wave formed by the superposition of the incident and the reflected waves from a rigid end. Also determine the amplitude of stationary waves formed at $x = 2$ meter. What will be the distance between consecutive nodes?
- (b) What are damped oscillations? Obtain the differential equation for damped oscillations and write its possible solution. Explain with corresponding sketches, when there can be very heavy damping, critical damping and weak damping.
- (c) Explain how very low temperatures can be produced by adiabatic demagnetisation.
- (d) Why an extended source is necessary to see colours in a soap-film? Non-reflecting surfaces are made by coating very thin films of a transparent material. Find the maximum thickness of such thin coatings given that $\lambda=5.5\times 10^{-5}$ cm and $\mu=5/4$.
6. (a) What are the essential conditions for observing the interference of light? Two coherent sources with intensity ratio 4:1 interfere. Find $I_{\max}/I_{\min}$.
- (b) Give Rayleigh's criterion for resolution. Why telescopes with larger objectives are better? The objective of the telescope at St. Palomer has a diameter of 5.08 m. What is the least distance on Moon which could be resolved by it? (Given distance of moon from the Earth = 3,84,000 km and $\lambda = 5890 \text{ \AA}$).
- (c) Describe the set-up of Michelson-Morley experiment. Why was a fringe shift expected in it? How are its negative results understood?
7. (a) The RMS speed of oxygen molecules at 0° C is 460 ms⁻¹. What would be the RMS speed of Argon molecules (Mol. wt. = 40 gm/mole) at 40° C and at what temperature this speed would be double than at N.T.P.?
- (b) Differentiate between Fresnel and Fraunhofer diffractions. How can one explain the Fresnel diffraction pattern due to a straight edge?
- (c) Sodium light is incident normally upon a plane transmission grating having 5000 lines/cm. Calculate the angular separation of the D_1 and D_2 lines in the first order spectrum. As this angular separation is very small [?], how can one magnify it 10 times? (Given: $\lambda_{D_1} = 5890 \text{ \AA}$ [?] and $\lambda_{D_2} = 5896 \text{ \AA}$)
8. Write short notes on any three of the following: (i) Geostationary satellites (ii) Applications of Bernoulli's equation (iii) Thermodynamic potentials (iv) Forced oscillations (v) Carnot cycle (vi) Holography