

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. Attempt any three of the following:
 - (a) Determine the speed of an electron which has kinetic energy 1 MeV. The energy equivalent to the rest mass of an electron is 0.51 MeV.
 - (b) The potential energy of a particle is given by $U = a \cos \alpha x$. Obtain the positions of stable equilibrium.
 - (c) Hydrogen and oxygen suffer Joule-Thomson expansion at room temperature. Discuss the results with reasons.
 - (d) A satellite is launched into a circular orbit close to the surface of the earth. Find an expression for the additional velocity that has to be imparted to the satellite to overcome the gravitational pull.
2.
 - (a) Distinguish between stream-line motion and turbulent motion. Hence define Reynold's number. A sphere of radius 0.1 cm moves through glycerine. A laminar flow is observed when the velocity of the sphere does not exceed 15 cm/s. At what minimum velocity of a sphere of radius 5 cm will the flow in water become turbulent? Viscosity coefficient for glycerine $\eta_{gly} = 14 \text{ p}$ and for water $\eta_{wat} = 0.011 \text{ p}$, and density of glycerine = 1.2 gm/cc.
 - (b) A stream of liquid of density ρ and speed v is directed against a plane surface at an angle θ with the normal to the surface. After striking the surface the liquid spreads over it. Find the pressure on the surface.
 - (c) State Kepler's laws and prove that for elliptical orbits the square of the period of a satellite is proportional to the cube of the semi-major axis.
3.
 - (a) Show that for forced oscillations amplitude resonance and energy resonance do not occur at the same frequency.
 - (b) What are precession and nutation? Show that the angular velocity of precession Ω is related to the angular momentum $\mathbf{L}$ and external torque $\boldsymbol{\tau}$ as $\boldsymbol{\Omega} \times \mathbf{L} = \boldsymbol{\tau}$. Assume $\Omega \ll \omega$.
 - (c) A body of mass m supported by a spiral spring causes an extension of d in the spring. The body is set in vertical oscillations of small amplitude. Find an expression for the periodic time of the oscillations.
4. (a) Write the expressions obtained from Einstein's and Debye's theories for the specific heat of solids. What is the basic difference between the two theories? Calculate the heat required to raise the temperature of a solid of mass m from T_1 to T_2 in the low temperature region.

- (b) Calculate the most probable speed v_p , the average speed $\langle v \rangle$ and the root-mean-square speed $\langle v^2 \rangle^{1/2}$ for hydrogen molecules at 273 K.
- (c) State Nernst's heat theorem. Taking the example of adiabatic demagnetisation show that no adiabatic process initiated at non-zero-temperature can lead to zero temperature.

SECTION 'B'

5. Answer any three of the following:
 - (a) The distance between the centres of oxygen and carbon atoms in a carbon monoxide molecule is 1.2 Å. Determine the position of the centre of mass of the molecule relative to carbon. (Assume atomic masses of carbon and oxygen as 12 and 16 respectively.)
 - (b) In the relativistic region, compare the relative increase in velocity with the relative increase in energy of a particle.
 - (c) Define entropy, Derive expressions for the entropy of a perfect gas in terms of (i) T and v (ii) T and p The symbols have their usual meanings.
 - (d) The solar constant on the lighted surface of the earth is given as 'J' Assuming solar radiation as black body radiation find an expression for the temperature of the photosphere of the sun.
6. (a) Obtain the intensity pattern due to Fraunhofer diffraction at two parallel slits. Each slit has a width 'a' and the separation between the slits is 'd'. How many interference fringes will appear in the central diffraction maximum, if $d=4a$?
- (b) Discuss the working principle of He-Ne laser indicating the transitions involved in the process. Determine the power output of a laser in which a 3.0 J pulse is delivered in 1.0 ns.
- (c) A left circularly polarized beam of light ($\lambda=6000$ Å) is incident on a quartz crystal (Optic axis parallel to the surface). Find the state of polarisation of the emergent beam. (Thickness of quartz crystal $=2.3 \times 10^{-5}$ m, $\mu_e=1.5538$, $\mu_o=1.5444$)
7. (a) Define thermodynamic temperature of a magnetic system. Discuss how cooling takes place due to adiabatic demagnetisation. Explain, why cooling due to adiabatic demagnetisation is important at low temperatures.
- (b) The density of gold in its proper frame of reference is 19.3×10^3 kg/m³ [?]. Determine its density in a frame of reference where its velocity is 0.9c. c is velocity of light in free space.
- (c) In a biprism experiment the fringe-width with light of wavelength $\lambda=5900$ Å is 0.43 mm. On introducing a mica sheet in the path of one of the interfering rays the central fringe shifts by 1.89 mm. If refractive index of mica is 1.59, calculate the thickness of the sheet.
8. Write short notes on any three of the following:
 - (a) Concept of negative temperature
 - (b) Michelson-Morley experiment
 - (c) Brownian motion
 - (d) Fourier transformation
 - (e) Gyroscope
 - (f) Fourier transformation