

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) What is meant by temporal and spatial coherence? Show that the coherence length $L = \lambda Q$, where λ is the mean wavelength and Q represents the purity of a spectral line.
- (b) A satellite has apogee and perigee heights above the surface of earth as 4000 km and 640 km respectively. Calculate the eccentricity of the orbit and semi-major axis. Radius of the earth is 6400 km.
- (c) The angular separation between two distant stars is 1 arc-second. If the effective wavelength of light is 5500 Å; what should be the diameter of the objective of a telescope so that the stars are just resolved?
- (d) A vacuum of the order of 10^{-11} cm of Hg is obtained in the laboratory. Estimate the number of molecules of gas per cubic centimeter at 27°C in that vacuum.

2. (a) A particle of mass m_1 moving with a velocity v_1 undergoes an elastic collision with a particle of mass m_2 at rest, in laboratory-frame. After the collision the first particle moves at a certain angle to the direction of its initial velocity, and this angle is Θ in laboratory-frame and ϕ in centre of mass-frame. If the ratio of masses (m_2/m_1) is a , show that Θ and ϕ are related as $\tan\phi = (\sin\Theta / (\cos\Theta + 1/a))$ [?].
- (b) A spherical body of mass 'm' and radius 'a' is falling through a viscous fluid. If it started from rest and η is coefficient of viscosity of the fluid obtain an expression for its velocity as function of time. What is meant by relaxation time? On what factors will it depend in this case?
- (c) What is Brownian motion? Deduce Einstein's formula for translatory Brownian motion of particles suspended in a liquid and hence determine the Avogadro's number.
3. (a) The potential energy for the interaction between two gas molecules can be represented by the function.

$$\phi(r) = -\phi_0 [2(r_0/r)^6 - (r_0/r)^{12}]$$

Where ϕ_0 and r_0 are constant. Prove that for small oscillations the frequency is given by $\omega = (144\phi_0/mr_0^2)^{1/2}$ Where m is mass of each molecule.

- (b) A Particle of mass m , moving with an initial velocity v_0 is acted on by a central repulsive inverse-square force, $F = k/r^2$. Show that the scattering angle ϕ depends on the impact parameter b as $\cot(\phi/2) = mv_0^2/kb$.

- (c) Write the equation of motion for an oscillator driven by a simple harmonically varying force. Obtain the condition for maximum energy transfer to the oscillator.
4. (a) State the principle of equipartition of energy. What are its limitations? Show that it is applicable only when the energy is a quadratic function of the associated variable.
- (b) Using Maxwell's thermodynamic relations show that the internal energy of an ideal gas at a constant temperature is independent of its volume while for a real gas it is a function of Volume also.
- (c) To what extent the pressure in a cathode ray tube must be reduced so that 90% of the electrons emitted by the cathode reach the anode which is at a distance of 20 cm from the cathode? The mean molecular radius of main constituent gases of atmosphere is $2\text{\AA}$ and the number of molecules at standard pressure (760 mm of Hg) is 3×10^{25} per m^3 .

SECTION 'B'

5. Answer any three of the following:
- (a) The coordinates of an event in an inertial frame S are $(25\text{ m}, 0, 0, 5 \times 10^{-8}\text{ s})$. What will be the coordinates of this event in another inertial frames S' moving with a velocity 0.6 c in + x-direction with respect to S. The origins of the two frames were coincident at $t=t'=0$
- (b) What is a quarter wave plate? Explain its use in the production and detection of circularly polarized light. For calcite for $\lambda=5472\text{ \AA}$, $\mu_O=1.659$ and $\mu_E=1.488$. If the minimum thickness of a plate that can be cut from calcite is $30\text{ }\mu\text{m}$, what should be the minimum thickness for preparing a quarter wave plate?
- (c) Explain the concept of entropy The specific heat C_p of a material depends on temperature T according to the relation: $C_p = a + bT + cT^2$ where a, b and c are constants, Derive an expression for the change in its entropy when the temperature changes from T_1 to T_2 .
- (d) Define Coriolis force. Obtain an expression for the Coriolis force. How does it account for the whirling of winds in opposite directions in Northern and Southern hemispheres?
6. (a) Show that the interference fringes obtained in Young's two slit experiment are hyperbolic in shape. Under what conditions these are expected to appear straight?
- (b) Obtain an expression for the ratio of the probabilities of stimulated and spontaneous emissions. What do you infer from this relation? How is population inversion interpreted thermodynamically?
- (c) A fine slit is illuminated by monochromatic light of wave-length $6000\text{ \AA}$. A thin wire is placed parallel to the slit and the diffraction pattern is observed on a screen at a distance of 1 m from the wire. In the shadow of the wire equidistant fringes of thickness 1.5 mm are observed. How do you explain this observation? Calculate the diameter of the wire also.
7. (a) How is absolute scale of temperature obtained with the help of Carnot cycle? Hence define absolute zero
- (b) State Bernoulli's theorem. A horizontal pipe has a cross-section of 10 cm^2 in one region and 5 cm^2 in another. The pressure of water in the two regions is $2.370 \times 10^5\text{ N/m}^2$ and $1.995 \times 10^5\text{ N/m}^2$ respectively. Calculate the amount of water flowing through the pipe per minute.
- (c) Describe the working principle of a three level solid state laser giving the transitions involved in the laser action.
8. Write short notes on any three of the following:
- (a) Stellar spectra
- (b) Specific heat of solids
- (c) Holography

- (d) Mass-energy equivalence
- (e) Solar constant
- (f) Fourier transformation