PHYSICS - I
(PHYS 1001)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The observation leading to Brewster law finds polarization in the
(a) reflected ray (b) refracted ray
(c) incident ray (d) ordinary ray.

(ii) In Young's double slit experiment if the fringe width for λ_1 (8000 Å) is 0.05cm, the fringe width for λ_2 (4000Å) will be
(a) 0.005 cm (b) 0.0025 cm
(c) 0.05 cm (d) 0.025 cm.

(iii) Formation of fringe pattern in Newton's Ring experiment is based on
(a) division of amplitude
(b) division of both amplitude and wave front
(c) division of wave front
(d) none of them.

(iv) Relaxation time of weakly damped oscillator,
(a) increases with damping factor
(b) decreases with damping factor
(c) independent of damping factor
(d) none of the above.

(v) Compton effect verifies
(a) particle nature of photon (b) wave nature of electron
(c) wave nature of photon (d) particle nature of electron.

(vi) Momentum of a photon of frequency ν is given by,
(a) $\frac{h\nu}{c}$ (b) $\frac{h\nu}{c^2}$ (c) $\frac{h\nu^2}{c}$ (d) not defined.

(vii) De Broglie wavelength of a relativistic quantum particle of rest mass m and kinetic energy E is,
(a) $\lambda = \frac{h}{\sqrt{E(E+2mc^2)}}$ (b) $\lambda = \frac{hc}{\sqrt{E(1+2mc^2)}}$
(c) $\lambda = \frac{hc}{\sqrt{E(E+2mc^2)}}$ (d) $\lambda = \frac{h}{\sqrt{2mE}}$.

(viii) In case of Compton scattering the maximum shift in wave length measured is
(a) 0.048Å (b) 0.024Å (c) 0.028Å (d) 0.148Å

(ix) The coordination number in BCC lattice is,
(a) 12 (b) 4 (c) 8 (d) 6.

(x) In NaCl crystal, the unit cell contains
(a) 4 molecules (b) 6 molecules
(c) 8 molecules (d) none of these.

Group – B

2. (a) Obtain the mathematical expression for the fringe shift that occur when a thin transparent medium is introduced in one of the paths of the interfering beams.

(b) A newton's ring experiment is done with two different media of refractive indices n_1 and n_2. If the radius of the 10th dark ring in the first case is 2.25 times that of the second, calculate the ratio of the refractive indices of the media involved.

(c) Write the expression of intensity for single slit diffraction pattern and identify the conditions of maxima and minima.

(d) How does ordinary light differ from LASER?

4 + 3 + (1 + 2) + 2 = 12

3. (a) A linearly polarized light wave is given by the expression **E**(z, t) = cos (kz - ωt)**i** + cos (kz - ωt)**j.** Determine the plane of polarization, plane of vibration and direction of propagation of the said wave. How can we transform it to a circularly polarized light?

(b) A plane polarized light of wavelength λ is incident on a thin quartz plate cut with faces parallel to the optic axis. The minimum thickness of the retardation plate for which the O-ray and E-ray waves will combine to produce plane polarized light is 't'. If μ and ν be the

refractive index and the velocity respectively of the ordinary ray what could be velocity of the extraordinary ray?

(c) A sheet of cellophane is a half-wave plate for light of $\lambda = 4\times10^{-5}$ cm. Assuming that there is negligible variation in refractive index with wavelength, how would the sheet behave with respect to the wave length of $\lambda' = 8\times10^{-5} cm$?

(3 + 2) + 3 + 4 = 12

Group – C

4. (a) Obtain the resultant vibration of a particle when subjected under two mutually perpendicular harmonic vibrations as given below:

$x = a\cos 2wt$ and $y = b\cos(2wt - \frac{\pi}{2})$. Draw the necessary Lissajous figure.

(b) By writing the equation of motion of a damped harmonic oscillator write down the condition of weakly damped oscillation. Define relaxation time.

(c) A mass less spring suspended from a rigid rod carries a mass of 200 gm at its lower end. It is observed that the system oscillates with a time period of 0.2 s and the amplitude of oscillation reduces to half of its initial value in 30 s. Assuming very weakly damped oscillation, calculate logarithmic decrement and spring constant.

(3 + 2) + (2 + 1) + (2 + 2) = 12

5. (a) A mechanical harmonic oscillator of mass m and stiffness constant k is subjected to a viscous damping force that is proportional to its velocity; the coefficient of damping force is 'b'. The oscillator is driven by a force $F = F_0 \sin wt$. Write down the differential equation for the vibration under this situation.

(b) Solve the above equation and explain the transient and steady state.

(c) Plot the amplitude vs frequency graph for a particle undergoing forced damped oscillation indicating amplitude resonance for various damping constants.

(d) Write down the differential equation of a series L-C-R circuit driven by sinusoidal voltage source. Then by identifying terms with a corresponding mechanical forced-damped oscillator, write down the condition for current resonance in the circuit.

1 + (3 + 2) + 3 + (1 + 2) = 12

Group – D

6. (a) Total energy(E) of a relativistic particle is μ times its kinetic energy(T). If the momentum of the particle is 'p' show that $T^2 = \frac{(pc)^2}{2\mu - 1}$.

(b) Plot the momentum (p) vs de Broglie wave-length (λ) graph of a particle. Two free particles with de Broglie wave lengths λ and 4λ, have same kinetic energy. Find the ratio of their masses.

(c) A photon of mass m and energy E is incident on a stationary electron target and the angle of Compton scattering of photon is θ. Show using non-relativistic kinetic energy that recoil energy of electron is, $\frac{E^2(1-\cos\theta)}{mc^2 + E(1-\cos\theta)}$.

(d) A γ-ray beam of wave length 1.8×10^{-2} Å is scattered by free electrons at an angle 90^0 with the incident beam. Calculate the Compton wave length shift.

3 + (1 + 2) + 4 + 2 = 12

7. (a) Write Planck formula for energy distribution of black-body radiation and derive the expression of the same for large wave-length limit. What is ultraviolet catastrophe?

(b) Write the statement of Heisenberg's uncertainty principle. The maximum uncertainty in the position of an electron in a nucleus is 2 × 1014 m. Find the minimum uncertainty in its velocity (given h = 6.63 × 10^{-34} Js).

(c) What is soft X-ray? Explain the phenomenon of Bremsstrahlung.

(2 + 2 + 2) + (1 + 2) + (1 + 2) = 12

Group – E

8. (a) Differentiate between continuous and characteristic X-ray spectrum.

(b) Obtain the mathematical expression for the perpendicular distance between successive planes in a crystal lattice in terms of the miller indices.

(c) In an X-ray diffraction experiment, the second order glancing angle was 30^0. Calculate the third order glancing angle, for the same set of planes.

(d) Within a cubic unit cell, sketch the following directions: $[\bar{1}10]$ and [001].

2 + 3 + 3 + (2 + 2) = 12

9. (a) Obtain the relation between the density ρ of crystalline material and lattice constant a of a simple cubic lattice.

(b) Define atomic packing fraction of a crystal. Find out the values of atomic packing fraction for BCC and FCC crystal.

(c) The atomic radius of an atom of silver (Ag) (FCC) is 0.157 nm and atomic weight is 108 g/mol. Calculate the lattice constant, atomic packing factor and the density of silver.

2 + (1 + 3) + (2 + 2 + 2) = 12