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Paper Code : PH-101

PHYSICS – I

Time Allotted : 3 Hours | *Full Marks* : 70

The figures in the margin indicate full marks.

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

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

   i) To obtain a circular Lissajous figure, the phase difference Φ and the amplitudes a and b of two mutually perpendicular SHM's are

   a) $\Phi = 0, a = b$ b) $\Phi = \pi/2, a = b$

   c) $\Phi = 0, a = 2b$ d) $\Phi = \pi/2, 2a = b.$

   ii) When O – ray & E – ray travel along the optic axis of an uniaxial crystal, then

   a) $\mu_e > \mu_o$ b) $\mu_e < \mu_o$

   c) $\mu_e = \mu_o$ d) $\mu_e = \frac{1}{\mu_o}$.

iii) Compton wavelength for a pacticte of rest mass m_0 is

a) $\frac{h}{m_0 c}$ b) $\frac{h^2}{m_0 c}$

c) $\frac{h}{m_0 c^2}$ d) $\frac{h}{m_0 c}$.

iv) If the equation of motion of an oscillator is given by $\ddot{x} + \frac{\gamma^2}{4} x + \gamma x = 0$, then the motion is

a) simple harmonic without damping

b) a critically damped simple harmonic

c) an overdamped simple harmonic

d) an underdamped simple harmonic.

v) The ratio of the nearest neighbour distance for SC, BCC and FCC is

a) $1 : \sqrt{2} : \sqrt{3}$ b) $1 : \sqrt{3} : \sqrt{2}$

c) $2 : \sqrt{3} : \sqrt{2}$ d) $2 : \sqrt{2} : \sqrt{3}$.

vi) Two waves having the intensities in the ratio of 9:1 produce interference. The ratio of maximum to minimum intensity is equal to

a) 1 : 81 b) 9 : 1

c) 4 : 1 d) 2 : 1.

vii) Holography is a method in which one

a) records the amplitude only

b) records the phase only

c) not only records the amplitude but also the phase of the light wave

d) records either the amplitude or the phase.

viii) In Fraunhofer diffraction, the incident wavefront is

a) plane
b) spherical
c) cylindrical
d) arbitrary.

ix) When two parallel ray of X-ray of wavelength λ, are incident at an angle θ on a crystal with lattice separation d, constructive interference would be observed when (N is an integer)

a) $N\lambda = 2d \sin\theta$
b) $N\lambda = d \sin\theta$
c) $N\lambda = d \sin 2\theta$
d) $N\lambda = 2d \sin 2\theta$.

x) The de Broglie wavelength of a thermal neutron is given by

a) $\frac{h}{\sqrt{2mkT}}$
b) $\frac{h}{\sqrt{3mkT}}$
c) $\frac{2h}{\sqrt{3mkT}}$
d) $\frac{h^2}{\sqrt{3mkT}}$.

xi) Ghost lines in grating spectra appear due to

a) regular arrangements of slits
b) irregular arrangements of slits
c) interference from many slits
d) polarization from many slits.

xii) In a ruby laser population inversion is achieved by

a) chemical reactions
b) inelastic collision between atoms
c) Joules heating
d) optical pumping.

xiii) If λ_r and λ_{nr} are the relativistic and non-relativistic wavelength of an electron respectively, then

a) $\lambda_{nr} > \lambda_r$ b) $\lambda_r > \lambda_{nr}$

c) $\lambda_r > \lambda_{nr}$ d) $\lambda_r > \frac{1}{\lambda_{nr}}$.

xiv) Energy emitted from the surface of a black body at an absolute temperature T is proportional to

a) T b) $T^{1/4}$

c) T^3 d) T^4.

xv) Heisenberg's uncertainty principle is the consequence of

a) wave nature of particle

b) wave particle duality

c) particle nature of wave

d) particle particle interaction.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following : $3 \times 5 = 15$

2. How are coherent sources produced in Young's double slit experiment ? Show that law of conservation of energy is not violated in case of interference. 2 + 3

3. a) Determine atomic packing fraction of FCC lattice.

b) X-rays of wavelength 1.54Å are used for the calculation of d_{100} plane of a cubic crystal, the Bragg's angle of 1st order reflection is 10°. What is the size of the unit cell ? 2 + 3

4. a) Explain Brewster's law.

   b) Show that when light is incident on a transparent substance at the polarizing angle, the reflected and the refracted rays are perpendicular to each other. 2 + 3

5. a) Show that for a particle executing SHM, the average kinetic energy is half the corresponding maximum energy.

   b) Determine the atomic packing fraction of FCC lattice. 3 + 2

6. a) What do you mean by population inversion ?

   b) Draw the energy level diagram of helium and neon laser transition. 2 + 3

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) Write down the Planck's law of frequency distribution of black body radiation.

   b) Show graphically how the energy density *vs* frequency plot of black body radiation is changed if the temperature is changed.

   c) Prove that the product of phase velocity and group velocity for a de Broglie wave is equal to the square of the velocity of light.

   d) Why in case of macroscopic bodies uncertainty principle is not relevant ?

e) When a particle moves with a velocity much less compared to the velocity of light in free space, shown that relativistic expression for KE approaches the classical result.

f) Derive Wien's displacement law from Planck's law of Black body radiation. 1 + 2 + 3 + 2 + 3 + 4

8. a) State de Broglie's hypothesis. Show that the relativistic de Broglie wavelength is given by

$$\lambda_{relativistic} = \frac{hc}{\sqrt{E_k(E_k + 2m_oC^2)}}$$

(The notations used have their usual significance)

b) Calculate the de Broglie wavelength of a thermal particle having temperature T.

c) Describe an experiment which verified de Broglie's hypothesis.

d) Why Compton effect cannot be observed with visible light but can be observed due to X-rays ?

(1 + 4) + 3 + 4 + 3

9. a) Why two independent sources of light of same wavelength cannot produce interference pattern ? Explain.

b) Newton's ring experiment was conducted first in air medium and then in water medium (*i.e*, water is inserted in between the plano-convex lens and glass plate). What happens to the diameter of a particular ring ?

c) In Young's double slit experiment, the distance between the two slits is 0.5 mm. The wavelength of the light used is 5000 Å and the separation between the source and the screen is 50 cm. Calculate the fringe width in this case.

d) In Newton's ring experiment the diameter of the 12^{th} ring changes from 1.50 cm to 1.35 cm, when a liquid is introduced between the lens and the plate. Calculate the refractive index of liquid.

e) Show that intensity distribution for diffraction in a single slit is given by,

$I = I_0 (\frac{\sin^2 \beta}{\beta^2})$, where $\beta = \frac{\pi \sin\theta}{\lambda}$. 2 + 2 + 3 + 3 + 5

10. a) State Malus law. A beam of polarized light makes an angle of 60° with the axis of the polaroid sheet. How much intensity of light is transmitted through the sheet ?

b) What is a retardation plate ? How can you distinguish between circularly polarized light and unpolarized light with the help of a quarter wave plate and a nicol prism ?

c) Why is optical pumping not generally employed in case of a gas LASER ?

d) Prove that the maximum recoil energy of a free electron of rest mass m_0 when stuck by a photon of wavelength λ is given by $E_{max} = \frac{2m_0c^2\lambda_c^2}{\lambda^2 + 2\lambda_c\lambda}$, here λ_c is the Compton wavelength of the electron.

(1 + 3) + (2 + 3) + 2 + 4

11. a) A particle is subjected to a harmonic restoring force and a damping. Its equation of motion is given by $m\frac{d^2x}{dt^2} = -sx - K\frac{dx}{dt}$. Under the condition of critical damping, find the expression for displacement as a function of time. Can you justify why this condition (critical damping) corresponding to the fastest non-oscillatory decay ?

b) A cubical block of side L cm and density d is floating in water of density ρ ($\rho > d$). The block is slightly depressed and released. Show that it will execute simple harmonic motion. Determine the frequency and time period of oscillation.

c) Establish the differential equation of simple harmonic motion and solve the equation.

(4 + 1) + 5 + 5