Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech (NEW)/SEM-2/PH-201/2011

2011

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) If the damping force on an one-dimensional harmonic oscillator of natural frequency ω_0, is $2bmv$, where m is the mass and v is the instantaneous velocity of the oscillator then the frequency of oscillation (when $b << \omega_0$) is

a) ω_0 b) b

c) $\omega_0\left(1-\frac{b^2}{2\omega_0^2}\right)$ d) $\omega_0\left(1+\frac{b^2}{2\omega_0^2}\right)$.

ii) Two mutually perpendicular oscillations with same frequency, amplitude but phase difference δ will produce closed curve with non-zero area enclosed

a) for all values of δ except δ = 0

b) only for $\delta = \frac{\pi}{2}$

c) for all values of δ except δ = 0 and δ = π

d) for all values of $\delta > \frac{\pi}{2}$.

iii) Example of weakly damped harmonic oscillator is

a) Dead-beat galvanometer

b) Tangent galvanometer

c) Ballistic galvanometer

d) Discharge of a charged capacitor through a resistance.

iv) Missing orders are found in case of double slit diffraction patterns due to

a) unequal value of two slit widths

b) superposition of diffraction minima and interference maxima

c) superposition of diffraction maxima and interference minima

d) oblique incidence of light.

v) How does reducing the slit separation, affect the appearance of the fringes in the double slit interference ?

a) The fringe width increases and the fringes are brighter

b) The fringe width increases but the brightness remains unchanged

c) The fringe width decreases and the fringes are brighter

d) The fringe width is unchanged but the fringes are less bright.

vi) Resolving power of microscope objective placed in air with light of wavelength λ_1 is the same when immersed in oil of refractive index μ and wavelength λ_2. Assuming the semivertical angle to be the same in these two cases then

a) $\lambda_1 = \mu \lambda_2$ b) $\lambda_2 = \mu \lambda_1$

c) $\lambda_1 \lambda_2 = \mu (\lambda_1 + \lambda_2)$ d) $\lambda_1 + \lambda_2 = \mu \lambda_1 \lambda_2$.

vii) For a doubly refracting crystal, the refractive indices for the ordinary and extraordinary rays are denoted by μ_o and μ_e. Which of the following relations is valid along the optical axis of the crystal ?

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

c) $\mu_e > \mu_o$ d) $\mu_o \leq \mu_e$.

viii) Which of the following schemes does not produce lasing action ?

a) Two level scheme b) There level scheme

c) Four level scheme d) Five level scheme.

ix) In holography, the 3D images are formed obeying the principle of

a) interference b) diffraction

c) polarization d) dispersion.

x) Number of oscillation modes for the electromagnetic standing waves of frequency γ for the cavity radiation is proportional to

a) $\gamma^{\frac{1}{2}}$ b) γ

c) γ^4 d) γ^2

where γ is the frequency of the wave.

xi) How fast must a particle travel so that its mass becomes twice its rest mass ?

a) $0{\cdot}5\ c$ b) $2\ c$

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

xii) Origin of continuous X-rays is due to the process of

a) ionization b) inner orbital transition

c) bremsstrahlung d) none of these.

xiii) The effective number of atoms per unit cell of an F.C.C. lattice is

a) 4 b) 6

c) 14 d) 1.

xiv) The interplanar distance d_{111} for a (111) plane of simple cubic crystal is

a) $\frac{a}{\sqrt{3}}$ b) $\frac{a}{\sqrt{2}}$

c) a d) $2a$.

xv) A proton accelerated through a potential difference of V has a certain de Broglie wavelength. In order to have the same de Broglie wavelength, an α-particle must be accelerated through a potential difference of

a) $8\ V$ b) $4\ V$

c) $\frac{V}{4}$ d) $\frac{V}{8}$.

GROUP – B
(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

2. If a damped harmonic oscillator, with natural frequency ω_o and damping force $2mbV$ (V = velocity, m = mass, b = a constant) is driven by a periodic force $Fe^{i\omega t}$ then the steady state displacement is given by

$$x = \frac{F}{m} \frac{e^{i\omega t}}{\sqrt{\left(\omega_0^2 - \omega^2\right) + i\, 2b\omega}}$$

Use this fact to show that at the velocity resonance the phase of the periodic force and the velocity is the same.

3. A mica sheet of thickness t and refractive index μ is introduced in the path of one of the interfering beams in Young's double slit experiment. Find out the linear displacement of the nth bright fringes in terms of 'μ' and 't'.

4. a) What is polaroid ? Give instances of its practical application.

   b) A quartz plate with thickness of 0·1436 mm is used as phase retardation plate. For what wavelengths in the visible region (450 – 800 nm) will it act as a quarter wave plate $\left(\mu_o = 1{\cdot}5443,\ \mu_e = 1{\cdot}55333\right)$. 1 + 1 + 3

5. Prove that the maximum recoil energy of a free electron of rest mass m_0 when struck by a photon of wavelength λ is given by $E_{\max} = \frac{2m_0 c^2 \lambda_c^2}{\lambda^2 + 2\lambda_c \lambda}$. Here λ_c is the Compton wavelength of the electron.

6. a) The spacing between principal planes of NaCl crystal is 2·82 Å. It is assumed that the first order Bragg reflection occurs at an angle 10°. Calculate the wavelength of *X*-rays.

   b) Find the atomic packing fraction of a B.C.C. structure. 2 + 3

GROUP – C
(Long Answer Type Questions)

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

7. a) A cubical block of side *L* cm and density *d* is floating in water of density ρ (ρ > *d*). The block is slightly depressed and released. Show that it will execute simple harmonic motion. Determine the frequency and time period of oscillation. 5

   b) Find the displacement as a function of time of a particle of mass *m* which is subjected to overdamped harmonic motion with natural frequency ω_o and damping force γV (*V* being the instantaneous velocity), given that the displacement is zero initially and the initial velocity is V_0. Sketch the displacement as a function of time. 7 + 3

8. a) Newton's ring arrangement is used with a source emitting two wavelengths $\lambda_1 = 600$ nm and $\lambda_2 = 590$ nm. It was found that the nth dark ring due to λ_1 coincides with the $(n + 1)$th dark ring due to λ_2. If radius of curvature of the lens is 0·9 m then find out the value of n and the diameter of the nth dark ring due to λ_2. 5

b) A plane transmission grating having 1500 lines/inch is being used under normal incidence of light.

i) What is the longest wavelength of light for which a spectrum can be seen ?

ii) What is the highest order spectrum that can be seen for the light of 589·3 nm wavelength ?

iii) The spectral line of 589·3 nm in the second order spectrum overlaps with another spectral line in the next order. Find wavelength of the other spectral line.

iv) Find the expression of the dispersive power for a given order.

v) If 90% of the width of the grating is covered, how the width of the spectral lines are changed ?

2 + 2 + 2 + 2 + 2

9. a) Define Einstein's A, B coefficient for spontaneous and stimulated emission. Derive the relations among them. 3 + 4

b) At what angle should light be incident on a glass plate of refractive index $\mu = 1{\cdot}5697$ to get a plane polarized light by reflection. 3

c) An analyzing nicol examines two adjacent plane polarized beams A and B whose planes of polarization are mutually perpendicular. In one position of the analyzer the beam B shows zero intensity. From this position, a rotation of 30° shows the two beams as of equal intensity. Deduce the ratio of two intensities I_A/I_B of the two beams. 3

d) Why is it necessary that the object beam and reference beam in holography are highly coherent ? 2

10. a) Discuss the action of optical resonator in a Baser device. What is the relation of the length of the resonator with the frequency of the laser beam ? 3 + 1

b) A ruby laser emits light of 693·95 nm wavelength. If 1 mole of Cr^{3+} ions are involved in population inversion process in a pulse, calculate the pulse energy in eV. 3

c) Calculate average energy of a cavity oscillator with frequency γ. How does this average energy vary with frequency in the high frequency limit ? 4 + 1

d) Derive Wien's displacement law from Planck's law of Black body radiation. 3

11. a) What voltage must be applied to an *X*-ray tube for it to emit *X*-ray with a minimum wavelength 30 pm. Deduce the formula that you use $\left[\frac{hc}{e} = 1{\cdot}24 \times 10^{-4} \text{ Vm}\right]$. 3 + 1

b) What are characteristic *X*-rays ? How are they produced ? 1 + 2

c) Describe the relation between the lattice constants and the angles between them in any one Bravais lattice other than cubic crystal system. 3

d) Find the Miller indices of all the principal planes of a cubic crystal system. 3

e) Aluminium is an *fcc* crystal with lattice constant a = 0·405 nm. Calculate the number of unit cells present in an aluminium foil of 0·005 cm thickness and two sides of 25 cm length. 2

12. a) What is de Broglie hypothesis of matter wave ? Discuss how Davisson and Germer proved this by an experiment. 1 + 4

b) If a particle of charge e and rest mass m_o is accelerated by a potential V then what is the de Broglie wavelength of the particle viewing the relativistic energy momentum relation. 4

c) The atoms in a solid possess a certain minimum zero point energy even at 0K while no such restriction holds for the molecules in an ideal gas. Use uncertainty principle to explain this statement. 2

d) An electron has de Broglie wavelength 2 pm. Find the phase and group velocities of its de Broglie wave given that the rest energy of an electron is 511 eV. 4