*Name* : .....

*Roll No.* : .....

*Invigilator's Signature* : .....

**CS/B. Tech (New)/SEM-1/PH-101/2011-12**

# 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) Resultant of two perpendicular simple harmonic motions of equal frequency and equal amplitude but a phase difference of $\pi$ radian is
      a) a straight line
      b) an ellipse
      c) a circle
      d) a spiral collapsing inward.

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

iii) An oscillator with natural frequency $\omega_0$ experiences a damping force and also a periodic force $A \cos(\Omega t)$. Amplitude of displacement velocity of the resulting steady state forced oscillation is studied with slow variation of $\Omega$, when $\Omega = \omega_0$

a) the displacement amplitude shows a maximum

b) the velocity amplitude shows a maximum

c) amplitudes of both displacement and velocity show maxima

d) amplitude of displacement shows minimum while the amplitude of velocity shows maximum.

iv) Diffraction occurs when the width of the narrow slit D is

a) comparable to the wavelength of the light used

b) equal to the wavelength of the light used

c) much greater than the wavelength of the light used

d) much smaller than the wavelength of the light used.

v) In Newton's ring experiment the diameters of the dark rings are proportional to

a) odd natural numbers

b) square root of the natural numbers

c) square root of the odd natural numbers

d) square of the natural numbers.

vi) A diffraction pattern is obtained with a plane transmission grating using a beam of red light. What happens after red light is replaced by blue light ?

a) The lines will shift towards lower angles

b) The lines will shift towards higher angles

c) The lines will disappear

d) No visible changes will be noticed.

vii) A rotating calcite crystal (a doubly refracting crystal) is placed over an ink dot. On seeing through the crystal, one finds

a) two stationary dots

b) two dots moving along a straight line

c) one dot rotating about the other

d) both dots rotating about a common axise.

viii) In He-Ne laser, Ne atom obtains energy

a) on collision with He atom

b) from chemical reaction

c) from optical pumping

d) from electrical pumping.

ix) Which of the following statements is not true about reconstruction of the holographic image ?

a) The hologram must be illuminated with a partially incoherent light

b) Both real image and virtual image are formed

c) The frequency of the illumination should be equal to that of the reference wave

d) The reconstructed image is a virtual image.

x) A proton, electron and a helium nucleus move with equal velocity. Rank their de Broglie wavelengths from longest to shortest.

a) Helium nucleus, proton, electron

b) Proton, electron, helium nucleus

c) Helium nucleus, electron, proton

d) Electron, proton, helium nucleus.

xi) The shift in wavelength in Compton effect is equal to Compton wavelength when the scattering angle is

a) zero b) $\pi/2$

c) $\pi$ d) $\pi/4$.

xii) If the kinetic energy of a particle is equal to its rest energy then

a) its mass is equal to its rest mass

b) its mass is double of its rest mass

c) its mass is half of its rest mass

d) its mass is $\sqrt{2}$ times its rest mass.

xiii) Number of oscillation modes for electromagnetic standing waves of frequency between $\nu$ to $\nu + d\nu$ in case of cavity radiation is proportional to

a) $\nu^3$ b) $\nu^2$

c) $\nu$ d) $\frac{h\nu}{e^{\frac{h\nu}{kt}} - 1}$.

xiv) The spacing between (340) planes in a face centered cubic crystal of lattice constant 10 nm is

a) 1 nm b) 2 nm

c) 4 nm d) 7 nm.

xv) An *X*-ray tube, while operated with an applied potential difference of 80000V, shows a current of 8 mA. The number of electrons striking per second on the target material is

a) $6 \cdot 4 \times 10^3$ b) $1 \times 10^7$

c) $5 \times 10^{11}$ d) $5 \times 10^{16}$.

## GROUP – B

### ( Short Answer Type Questions )

Answer any *three* of the following.

$3 \times 5 = 15$

2. a) Derive the expression for the total energy of a simple harmonic oscillator and show that it is constant and proportional to the square of the amplitude.

   b) If an oscillator's motion is described by

   $x = e^{-\beta t} \sin \Omega t$

   where $t$ is the time, then calculate its logarithmic decrement. 3 + 2

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

4. a) Find the ratio of Einstein's coefficients of spontaneous and stimulated emission.

b) Describe how the optical resonator in a laser setup is used to ensure that the frequency spread of the output light is very small. 3 + 2

5. A particle of mass $m$ is constrained to move in one dimension and trapped in an infinite potential well of width $a$. Estimate its ground state energy from uncertainty principle. Sketch a graph of this energy with the width $a$. 4 + 1

6. Draw a diagram showing the behaviour of X-ray intensity with wavelength. Distinguish between continuous and characteristic X-ray spectra. Derive short wavelength limit of continuous spectra. How are the characteristic spectra generated ? 1 + 1 + 2 + 1

## GROUP – C

### ( Long Answer Type Questions )

Answer any *three* of the following. $3 \times 15 = 45$

7. a) Find the frequency of oscillation of an underdamped harmonic oscillator of mass $m$, in terms of its natural frequency $\omega_0$ and damping constant $\gamma$ (where $-\gamma v$ is the damping force, $v$ being the velocity). 3

b) If the same oscillator is driven by an external force, $F = F_0 \cos \Omega t$, then find the phase difference between the displacement and the driving force in the steady state. 5

c) A series *L-C-R* circuit is driven by a.c. source of frequency Ω. Write down the differential equation the charge across the capacitor should satisfy. Identify the parameters of forced damped oscillator in terms of *L-C-R*. Find the frequency at which the current in this circuit in maximum. You have to deduce the necessary formula from the differential equation. (You may use your results of part (b) of this question) 1 + 1 + 5

8. a) In Young's double slit experiment, the slits are 0·2 mm apart and the screen is 1·5 m away. It is observed that the distance between the central bright fringe and the fourth dark fringe is 1·8 cm. Find the wavelength of light. 3

b) Write the expression of intensity (explaining the symbols) distribution for Fraunhoffer diffraction due to a double slit. Draw the distribution graphically. 2 + 1

c) Find the conditions of diffraction minima and interference maxima from the above expression. 2 + 2

d) In a double slit experiment if the slit width is 2 mm and the separation between the slits is 4 mm then find the missing orders. Derive the formula that you use. 3

e) Define resolving power of a grating. What factors does it depend upon ? 1 + 1

9. a) Using Brewster's law show that light incident on a transparent substance at polarising angle gives reflected and refracted rays at right angles to each other. 3

b) Describe how circularly polarized light and unpolarized light may be distinguished by experiment. 3

c) Unpolarized light is incident on two polarizing sheets placed on top of the other. Each sheet reduces the intensity of unpolarized light by 50%. What must be the angle between the characteristic directions of sheets if the intensity of the transmitted light is $\frac{1}{3}$ of the intensity of the incident beam. 3

d) A quarter wave plate is fabricated with smallest possible thickness for wavelength of 589·3 nm. What phase retardation will be obtained with this plate with light having wavelength of 435·8 nm. You may neglect the variations of refractive indices with wavelength for this problem. 3

e) Describe how the phase information of an object wave may be recorded in a holographic plate. 3

10. a) Describe the construction of a ruby laser. Also discuss how population inversion is achieved in ruby laser with clearly drawing the energy diagrams. Discuss whether this result is suitable for continuous or pulse mode operation. 2 + 2 +1

b) Show that the total energy per unit volume of a black body radiation is proportional to the fourth power of the absolute temperature. 3

c) Write down the equation describing mass energy equivalence. From that relation show that if a particle is moving with a velocity much smaller that of light then the kinetic energy is given by $\frac{1}{2} m_o \nu^2$, where $m_o$ is the rest mass and ν is the velocity of the particle. 2

d) *X*-ray of wavelength $0 \cdot 2 \text{ Å}$ is scattered by a stationary particle of Compton wavelength of 2·43 pm at an angle $45^\circ$. Calculate the wavelength of the scattered ray and the kinetic energy of the recoiled particle. 3

e) If a beam of electron is maximally diffracted from a crystal of interplanar separation *d*, at an angle θ then show that the accelerating voltage *V* for the beam of electron is given by

$$V = \frac{1}{2me} \left( \frac{h}{2d \sin \theta} \right)^2$$

where *m* and (–*e*) are the mass and charge of an electron and *h* is Planck's constant. 2

11. a) It is found that the maximum possible kinetic energy of an electron emitted by a radioactive nucleus of radius $10^{-14}$ m is 4 MeV. Then show that the electron did not exist in the nucleus before the radioactive decay. 3

b) Light of wavelength 5893 $\mathring{A}$ falls on a material of work function, $\phi$ = 1·90 eV. Calculate the energy of incident photon and the wavelength of the most energetic photoelectron ($h = 6 \cdot 62 \times 10^{-34}$ Js, $c = 3 \times 10^{8}$ m/s, mass of electron = $9 \times 10^{-31}$ kg, charge of electron, $e = 1 \cdot 6 \times 10^{-19}$ C) 2 + 3

c) Discuss why the phenomenon of photoelectric effect cannot be explained from the wave theory of light. 4

d) Deduce Wien's displacement law from Planck's law of black body radiation. 3

12. a) Define primitive cell. Are all unit cells primitive ? 2

b) Deduce the interplanar space of a simple cube of lattice constant *a*, for the planes ( *hkl* ). 4

c) In a certain crystal, the crystal planes of Miller indices (110) having a separation of 1·12 $\mathring{A}$ show X-ray diffraction. Calculate up to which order, Bragg's reflection can be observed. 3

d) In a triclinic crystal, a lattice plane makes intercepts of length $a$, $2b$ and $-c/2$. Find the Miller indices of the plane. 3

e) Calculate the lattice constant of a substance having *fcc* lattice, molecular weight 60·2 and density 6250 kg/ $m^3$. Avogadro number = $6{\cdot}02 \times 10^{23}$. 3