Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech/SEM-2/PH-201/2010

2010
ENGINEERING PHYSICS

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) The average energy of a free electron in a metal at absolute zero is

   a) zero

   b) more than $\frac{1}{2}E_f$

   c) less than or equal to $\frac{1}{2}E_f$

   d) equal to E_f when E_f is the Fermi level.

ii) In an interference pattern produced by the identical coherent sources of monochromatic light, the intensity at the site of central maximum is I. If the intensity at the same spot when either of the two slits is closed is I_0, we must have

a) $I = I_0$

b) $I = 2I_0$

c) $I = 4I_0$

d) I and I_0 are not related.

iii) Optic axis in a crystal is a

a) particular direction perpendicular to which ordinary and extraordinary rays travel with the same velocity

b) particular plane along which ordinary ray travels faster than extraordinary ray

c) particular direction along which ordinary and extraordinary rays travel with the same velocity

d) particular direction along which extraordinary rays cannot travel.

iv) The resolving power of a grating having number of rulings exposed in the *n*th order is

a) $\frac{n}{N}$ b) nN

c) $\frac{N}{n}$ d) $\frac{N}{n^2}$.

v) In a single slit Fraunhofer diffraction, when the slit width is increased the width of the central maximum

a) increases

b) decreases

c) remains unchanged

d) may increase or decrease and that depends upon the initial value of the slit width.

vi) A black body is something which

a) does not emit any radiation in any temperature

b) in room temperature absorbs more energy than it radiates

c) it absorbs incident radiations of all frequencies completely

d) absorption coefficient varies with the third power of frequency.

vii) Work function of a metal may be obtained by irradiating the metal surface with light and from

a) the x-intercept of the stopping potential *vs* frequency plot

b) the slope of the stopping potential *vs* frequency plot

c) the y-intercept of the intensity *vs* photocurrent plot

d) the slope of the photocurrent *vs* frequency plot.

viii) Group velocity of the wave packet associated with a particle of energy E and momentum P is

a) $\frac{d^2p}{dE^2}$ b) $\frac{dp}{dE}$

c) $\frac{dE}{dp}$ d) $\frac{dE^2}{dp}$.

ix) If $f(x)$ denotes the wave function of a particle in a one-dimensional box then the dimension of $f(x)$ is of

a) length

b) $\frac{1}{\sqrt{\text{length}}}$

c) none, $f(x)$ is dimensionless

d) $\frac{1}{\text{length}}$.

x) If x-component of the momentum operator, $\hat{p}_x$, is represented by $-i\hbar\frac{\partial}{\partial x}$, then the commultator of $\hat{x}$ and $\hat{p}_x^2$, $\left[\hat{x}, \hat{p}_x^2\right]$ is represented by (here $\hat{x}$ is the position operator)

a) $-\hbar^2\frac{\partial^2}{\partial x^2}$ b) $i\hbar$

c) $2\hbar^2\frac{\partial}{\partial x}$ d) zero.

xi) Example of a boson is

a) neutron

b) deuterium nucleus

c) proton

d) positon.

xii) The coordination number for BCC structure is

a) 6 b) 8

c) 12 d) 4.

xiii) The activator action in Ruby laser is

a) Aluminium

b) Oxygen

c) Gron

d) Chromium.

xiv) The angle between the crystal planes (1, 0, 0) and (0, 0, 1) in SC structure is

a) zero b) 90°

c) 45° d) 135°.

xv) If the power output of an optical fibre is $\frac{1}{10}$th of the power launched into it then the attenuation loss is

a) 10 dB b) 1 dB

c) 0·1 dB d) 100 dB.

GROUP – B
(Short Answer Type Questions)

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

2. a) A film of oil of refractive index 1·70 is placed between plane glass plate and a plan convex lens. The radius of curvature of the les is 1 metre. Determine the radius of the 10th dark ring formed in the Newton ring set-up given that the wavelength of light is 6000 $\mathring{A}$ 3

   b) State and explain Malus's law of polarization. 2

3. a) A light of wavelength 500 nm is incident normally on a slit of variable width and large length. A detector is placed at a large distance on the other side at an angle of 20° with the normal. For that width of the slit would the receiver show zero intensity ? 2

   b) How are continuous X-rays produced ? Find out the relation between the accelerating voltage of the X-ray tube and the minimum wavelength of X-ray produced.

   1 + 2

4. a) If m_0 is the rest mass of electron and C is the velocity of light and the kinetic energy of an electron is equal to its rest energy then find its de Broglie wavelength in terms of Planck's constant m_0 and C. 3

   b) If a system has two eigenstates ψ_1 and ψ_2 with eigenvalues E_1 and E_2, under what condition, will linear combination $(\psi = a\psi_1 + b\psi_2)$ be also an eigenstate ? 2

5. a) If the wave function (x) of quantum mechanical particle is given by

$\Psi(x) = a \sin(\pi x/L)$ for $0 \le x \le L$

$= 0$ otherwise,

then determine the value of a.

Also determine the value of x where probability of finding the particle is maximum. 2 + 2

b) Mention one application of graded index optical fibre. 1

6. a) A system has non-degenerate single particle states with energy levels 0, E, 2E, 3E. Three particles are to be distributed in these states such that the total energy is 6E. Write down in each case all possible microstates assuming that the particles obey M-B statistics or F-D statistics. 4

b) What is acceptance angle of an optical fibre ? Explain with a diagram. 1

GROUP – C
(Long Answer Type Questions)

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

7. a) Fraunhofer double slit diffraction pattern is observed in the focal plane of a lens of focal length 50 cm. The distance between two maxima adjacent to principal maxima is 5 mm and the fourth order is missing. Find the width of each slit and the distance between their centres. Given, $\lambda = 5000$ Å. 5

b) Write down the expression for intensity distribution of single slit diffraction pattern and explain the symbol used. Sketch how the intensity varies with angle of diffraction, θ. Find the values of the angles at which minima are located. Also find the condition that θ satisfies in order to be the position of a secondary maximum. 2 + 2 + 4

c) In a Young's double slit interference experiment distance between the coherent sources is 1·15 mm. Calculate the fringe width that would be observed on a screen placed at a distance of 85 cm from the source. The wavelength of light used is 5893 $\mathring{A}$. 2

8. a) Calculate the minimum thickness of a calcite plate which would convert plane polarized light into circularly polarized light. $\mu_e = 1{\cdot}486$ and $\mu_o = 1{\cdot}658$ and $\lambda = 5890\ \mathring{A}$. 2

b) What is Brewster's angle ? What is the value of this angle for glass of refractive index 1·5 immersed in water of refractive index 1·33 ? 1 + 2

c) What do you mean by temporal and spatial coherence ? Define coherent length. 3

d) Find the relation between lattice constant and density of the crystalline material for a cubic cell. 3

e) In a certain crystal, the crystal plane of Miller indices (110) has a separation 1·12 $\mathring{A}$. If these planes show X-ray diffraction with wavelength 1·54 $\mathring{A}$, calculate up to which order, Bragg's reflection can be observed. 3

f) What is a Bravais lattice ? 1

9. a) What is Compton shift ? 2

b) Find the change in wavelength of an X-ray photon when it is scattered through an angle of 135° C by a free electron. Use approximate values of the constants. 2

c) Why in case of macroscopic bodies uncertainty principle is not relevant ? 1

d) Describe photoelectric effect. How does classical theory fail to explain this effect ? 2 + 2

e) The ground state and the excited state normalized wave functions of an atom are ψ_0 and ψ_1, respectively, the corresponding energy being E_0 and E_1. If the probability of finding the atom in the ground state is 90% and that for the excited state is 10%, then find the average energy of the atom. Also determine the normalized wave function of the atom. 2 + 2

f) Show that the momentum of a photon of frequency ν is given by $p = \frac{h\nu}{c}$, where h is Planck's constant and C is the velocity of light in vacuum. 2

10. a) A particle, of mass m, moving in three dimensions is confined within a box $0 < x < a$, $0 < y < b$, $0 < z < c$. (The potential is zero inside and infinite outside.) Write down Schrödinger equation for the particle. By considering a stationary state wave function of the form $\chi(x, y, z) = f_1(x) f_2(y) f_3(z)$, show that the allowed energies are $E = \frac{\pi^2 \hbar^2}{2m}\left(\frac{n_1^2}{a^2} + \frac{n_2^2}{b^2} + \frac{n_3^2}{c^2}\right)$. What is the degeneracy of the first excited energy level when $a = b = c$? Explain. What is the ground state energy ?

1 + 4 + 2 + 1

b) Show that the group velocity of a wave packet associated with a particle is same as the particle velocity. 3

c) Write down Planck's law of frequency distribution of Black body radiation. Convert the expression into the wavelength distribution and find out the limiting form of this distribution at very small wavelengths. How does this result compare with the predictions from Rayleigh-Jeans formula ? 1 + 2 + 1

11. a) Write down the time-dependent Schrödinger equation explaining the symbols used. Derive time-independent Schrödinger equation assuming that the potential is time independent. 1 + 2

b) What are Fermions ? Give two examples. 1 + 1

c) Write the expression of B-E distribution law and derive Planck's back body radiation law from B-E statistics.

1 + 6

d) Sketch the Fermi distribution for $T = 0$ and $T > 0$ and explain. 3

12. a) Define the following : 3

i) Microstate.

ii) Macrostate.

iii) Thermodynamic probability.

b) What do you mean by 'spontaneous' and 'stimulated' emission of radiation ? Why is population inversion necessary in a laser ? 2 + 2

c) Describe He-Ne laser source with relevant energy level diagram. 6

d) Find the atomic packing factor for body centred cubic and face centred cubic crystals. 2