B.TECH/AEIE/CSE/ECE/4TH SEM/PHYS 2001 (BACKLOG)/2022

PHYSICS - II
(PHYS 2001)

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

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and <u>any 5 (five)</u> from Group B to E, taking <u>at least one</u> 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) Find the degrees of freedom of the system where two particles connected by a rigid rod moving freely in a plane.
(a) 2 (b) 3 (c) 6 (d) 0.

(ii) For a particle trapped in a box of length l, the value of the expected average is
(a) $\frac{1}{l}$ (b) $\frac{2}{l}$ (c) $\frac{l}{2}$ (d) l.

(iii) Which one of the following functions is an eigen function of the operator $\frac{d^2}{dx^2}$?
(a) $c\ lnx$ (b) $c\ x^2$ (c) $c\ e^{-mx}$ (d) $\frac{c}{x}$

(iv) Which one of the following is fermion?
(a) Photon (b) Electron (c) Phonon (d) Alpha particle

(v) The number of ways in which 2 fermions can be arranged in 3 energy states is
(a) 1 (b) 2 (c) 3 (d) 6

(vi) The number of microstates for n particles in two compartments obeying MB statistics
(a) n (b) 2^n (c) n^2 (d) 2^{n+1}

(vii) The relation between three electric vectors E, D and P is
(a) $\vec{D} = \varepsilon_0(\vec{E} + \vec{P})$ (b) $\vec{D} = (\vec{E} + \varepsilon_0\vec{P})$
(c) $\vec{D} = \varepsilon_0\vec{E} + \vec{P}$ (d) $\vec{D} = \frac{1}{\varepsilon_0}(\vec{E} + \vec{P})$

(viii) The average energy of an electron at T = 0K in a metal in terms of energy E_f at the Fermi level is
(a) $\frac{2}{3}E_f$ (b) $\frac{1}{3}E_f$ (c) $\frac{3}{5}E_f$ (d) $\frac{3}{4}E_f$

(ix) The number of generalized coordinates necessary to describe the motion of a particle in a circular wire of radius a is/are

(a) one (b) two (c) three (d) none of these.

(x) The velocity of an electron from E-k curve is

(a) $v = \frac{1}{\hbar}\frac{dE}{dk}$ (b) $v = \hbar\frac{dE}{dk}$ (c) $v = \frac{1}{\hbar}\frac{d^2E}{dk^2}$ (d) $v = \frac{\hbar}{\left(\frac{dE}{dk}\right)}$

Group- B

2. (a) What is meant by cyclic coordinate? State the conservation theorem of generalized momentum.

(b) What are the advantages of the Hamiltonian formulation over the Lagrangian formulation? Derive the Hamiltonian and Hamiltonian equation of motion for a particle falling freely under the influence of gravity.

(c) Define holonomic constraint with one example.

(2 + 2) + (2 + 4) + 2 = 12

3. (a) What is a wave function for a moving particle? Mention four points on its physical significance.

(b) If a wave function of a quantum mechanical particle is given by

$\varphi(x,t) = A\,Sin\left(\frac{\pi x}{L}\right)$ for $0 \le x \le L$

$= 0$ for $0 \ge x \ge L$

Find the value of A from normalization condition. Also find the value of x corresponding to maximum probability of finding the particle for the above system.

(c) Prove that $[\hat{A},\hat{B}] = -[\hat{B},\hat{A}]$ where $\hat{A}$ and $\hat{B}$ are two operators.

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

Group - C

4. (a) A system has non-degenerate energy levels with energies are 0, 1, 2, 3 units respectively. Three particles are to be distributed in these energy levels so that the total energy of the system is 3 units. Find the number of macrostates and corresponding microstates if the particles obey MB or FD or BE statistics. (You can find macrostates and microstates for any one statistics)

(b) Calculate the Fermi energy at 0 K of metallic silver containing one free electron per atom. The density and atomic weight of silver is 10.5 gm/cm^3 and 108 respectively.

(c) Write down the Fermi-Dirac distribution function and show graphically the variation of f(E) with E for T = 0 K and T > 0 K in metal.

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

5. (a) Write down the Bose-Einstein distribution function and hence obtain Planck's formula for black body radiation.

(b) Distinguish MB, FD and BE statistics mentioning at least two characteristics.

(c) Using Fermi-Dirac distribution, Calculate the concentration of electron in the conduction band of an intrinsic semiconductor.

(2 + 4) + 2 + 4 = 12

Group - D

6. (a) What are polar and non-polar dielectrics? Find out the relation between dielectric constant and electrical susceptibility.

(b) A capacitor uses a dielectric material of dielectric constant is 8. It has an effective surface area of 0.036 m^2 with a capacitance of 6μF. Calculate the field strength and dipole moment per unit volume if a potential difference of 15 V exists across the capacitor.

(c) Define electric polarizability? What are the different kinds of polarizabilities may appear in a dielectric material?

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

7. (a) Define magnetic dipole moment. An electron moving around the nucleus in a circular orbit at a constant linear speed then develop the expression of Bohr magneton and estimate its value?

(b) Draw the B-H curve for ferromagnetic materials and identify the retentivity and the coercive field on the curve.

(c) Define soft and hard magnetic material with one example.

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

Group - E

8. (a) The energy-wave vector dispersion relation for a one dimensional crystal of lattice constant ‘a’ is given by $E(\kappa) = E_0 - \alpha - 2\beta \cos ka$, where E_0, α, β are positive constants.

   (i) Find the expression for the velocity of the electron as a function of κ.
   (ii) For what value of κ, the velocity is maximum?
   (iii) Find the difference between the top and the bottom of the energy band.

(b) State and explain Bloch theorem for an electron in a periodic lattice in one dimension.

(c) The so called E-k relation in a band structure is given by $E = a + bk^2$. Find the group velocity of a carrier.

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

9. (a) Distinguish between types I and type II superconductors. Name some materials belonging to these two types of superconductors.

(b) Establish London equation of superconductivity in terms of magnetic field induction and hence describe Meissner effect?

(c) What is the critical magnetic field for a superconductor? How does it vary with temperature?

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