Group – E

8. (a) Define super conductivity. Why superconducting state is said to be perfectly diamagnetic.

   (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) + 3 = 12

9. (a) The energy versus wave vector relationship for a conduction electron in a semiconductor is $E = \frac{4\hbar^2 k^2}{m_0}$. Determine the electron effective mass.

   (b) The energy-wave vector dispersion relation for a one dimensional crystal of lattice constant 'a' is given by $E(\kappa) = E_0 + 3\alpha\kappa^2 + 2\beta\kappa^4$, where E_0, α, β are positive constants. Find the expression for the velocity of the electron as a function of κ. For what value of κ the velocity is maximum?

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

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

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 any 5 (five) from Group B to E, taking at least one 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) Ferrites are example of
   (a) diamagnetism (b) paramagnetism
   (c) ferromagnetism (d) ferrimagnetisms.

   (ii) The dimension of $\mu_0\varepsilon_0$ is
   (a) $L^{-2}T^{-2}$ (b) $L^{-2}T^{2}$ (c) LT^{-1} (d) $L^{-1}T^{-1}$.

   (iii) Which of the following function is an eigen function of the operator $\frac{d^2}{dx^2}$?
   (a) $\emptyset = clnx$ (b) $\emptyset = cx^2$ (c) $\emptyset = ce^{-mx}$ (d) $\emptyset = \frac{c}{x}$.

   (iv) The 1st excited state energy of a particle moving in a one-dimensional potential box is given in terms of length l of the box by
   (a) $\frac{4h^2}{8ml^2}$ (b) $\frac{h^2}{8ml^2}$ (c) $\frac{2h^2}{8ml^2}$ (d) $\frac{4\hbar^2}{8ml^2}$

   (v) The number of meaningful ways in which 3 fermions can be arranged in 3 compartments is
   (a) 1 (b) 3 (c) 6 (d) 9.

   (vi) The operator corresponding to the momentum of moving particle is
   (a) $\hat{p} = -i\hbar\frac{\partial}{\partial x}$ (b) $\hat{p} = i\hbar\frac{\partial}{\partial t}$
   (c) $\hat{p} = \hbar\frac{\partial}{\partial x}$ (d) $\hat{p} = -\frac{1}{i\hbar}\frac{\partial}{\partial x}$

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

(viii) The density of charge carrier in a pure semiconductor is proportional to
(a) $e^{\frac{-E_g}{KT}}$ (b) $e^{\frac{-E_g}{2KT}}$ (c) $e^{\frac{-2E_g}{KT}}$ (d) $e^{\frac{-E_g}{T}}$

(ix) The lagrangian of a system is a function of
(a) q_j, p_j, t (b) $q_j, \dot{q}_j, t$ (c) $\dot{p}_j, q_j, t$ (d) $p_j, \dot{q}_j, t$

(x) The paramagnetic susceptibility of a material varies as
(a) T (b) $\frac{1}{T}$ (c) T^2 (d) $\frac{1}{T^2}$

Group – B

2. (a) Write down the constraint equations for a particle slipping down an inclined plane and also derive the Lagrange equation of motion for the said system.

(b) If Lagrangian of the system is independent of the time, show that the Hamiltonian of the system is conserved

(c) The Hamiltonian of a system is given by H = ½$(p^2 + q^2)$. Where p and q are canonically conjugate variables. Write the Hamilton's equations of motion. Hence show that $\ddot{p} = -p$ for the system.

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

3. (a) What is the physical interpretation of wave function? How is wave function related to the probability of finding a particle at any point in space at a given time?

(b) If the wave function $\varphi(x)$ of a quantum mechanical particle is given by $\varphi(x) = a\ sin\frac{\pi x}{L}$, for $0 \le x \le L$
$= 0$, for $0 \ge x \ge L$, then determine the value of a. Also determine the value of x where the probability of finding the particle is maximum.

(c) An electron is bound by potential which closely approaches an infinite square well of width $2.5 \times 10^{-10} m$. Calculate the lowest three permissible quantum energies the electron can have.

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

Group – C

4. (a) Plot the Fermi distribution function for T = 0K and T > 0K in metal and explain their significance.

(b) Assume that in Tungsten (At. Wt. 183.8 and density 19.3 gm/cc) there are two free electrons per atom. Calculate the Fermi-energy and electron density. [Mass of electron= 9.1×10^{-28} gm; Avogadro's number = 6.02×10^{-23} and h = 6.62×10^{-27} erg-sec]

(c) Show that the average speed of the free electron at 0K is $\frac{3}{4}th$ of the Fermi velocity (v_F). [Given that: $g(E)dE = 4\pi V(2m/h^2)^{3/2}E^{1/2}dE$, symbols have their usual meaning]

(d) Obtain Planck's formula for black body radiation using B-E statistics.

3 + 3 + 3 + 3 = 12

5. (a) Using Fermi-Dirac distribution, Calculate the concentration of electrons in the conduction band of an intrinsic semiconductor.

(b) Four particles are distributed into three energy levels having energies 0, E, 3E so that the total energy is 6E. If the levels are degenerate with degeneracy 2, 2, 3 respectively, find out the macrostates and the corresponding microstates for M-B particles, F-D particles and B-E particles.

(c) Compare M-B, F-D and B-E statistics mentioning at least three characteristics.

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

Group – D

6. (a) Establish the relation between electronic polarizability and atomic volume of a dielectric material.

(b) An assembly of parallel plate capacitors having area 6.45×10^{-4} m^2 and plate separation 0.002 m is connected with external potential 10 V. If the capacitors filled up with a dielectric material with dielectric constant value of 6.0, calculate (i) value of capacitance (ii) amount of charge stored on each plate (iii) value of electric displacement vector.

(c) Define H in terms of B and M for a linear magnetic material. Give an example of a nonlinear magnetic material.

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

7. (a) Define magnetization. Obtain the relation $\mu = \mu_0(1 + \chi_m)$, symbols have their usual meaning.

(b) Compare diamagnetic, paramagnetic and ferromagnetic substances.

(c) In hydrogen atom, an electron revolves around a nucleus in an orbit of 0.54×10^{-10} m radius. If the frequency of revolution of an electron is 6.8×10^{15} Hz, find the magnetic moment of the orbiting electron and calculate numerical value of Bohr magneton.

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