7. (a) Write down the relation between magnetization $\vec{M}$, magnetic field intensity $\vec{H}$, and magnetic flux density $\vec{B}$ within a material and hence establish the relationship between relative permeability and magnetic susceptibility for a linear magnetic material.

   (b) Draw the B-H curve for a ferromagnetic material and identify the retentivity, and coercive field on the curve. What do you mean by hysteresis loss?

   (c) Calculate the torque on a rectangular current loop in a uniform magnetic field, $\vec{B}$ and hence show that it can be identified as a magnetic dipole. What is its magnetic dipole moment?

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

Group – E

8. (a) Define the term 'effective mass of an electron'. Is it different from the free electron mass? The energy versus wave vector relationship for a conduction electron in a semiconductor is $E = \frac{5\hbar^2 k^2}{m_0}$. Determine the electron effective mass.

   (b) Write down the London equation of superconductivity in terms of magnetic field induction and hence describe Meissner effect.

   (c) Calculate the number density of electrons in a material for which London penetration depth is $\lambda = 0.8 \times 10^{-8} m$. (take $\mu_0 = 4\pi \times 10^{-7}$ in SI unit)

   (d) Write the mathematical expression for the critical magnetic field for a superconductor at varying temperature. Draw the graph.

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

9. (a) State Bloch's theorem in one dimension.

   (b) What are the basic features of the Kronig-Penney model? Mention at least two points.

   (c) The relation between Bloch wave vector $\vec{K}$ and free particle wave vector $\vec{k}$ in Kronig-Penney model is given by $Cos\, Ka = Cos\, ka + \frac{\Omega}{k} Sin\, ka$, where Ω is a positive constant. Explain graphically the development of band gap in view of the above relation.

   (d) The energy-wave vector dispersion relation for a one dimensional crystal of lattice constant 'a' is given by $E(\kappa) = E_0 - 2\alpha\kappa^2 + 3\beta\kappa^4$, 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?

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

B.TECH/AEIE/CSE/ECE/4TH SEM/PHYS 2001/2017

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) Which one of the following is an acceptable wave function of a quantum particle?
   (a) x (b) e^{-x^2} (c) x^2 (d) cos x.

   (ii) The operator corresponding to the energy of moving particle is
   (a) $\hat{E} = -i\hbar\frac{\partial}{\partial t}$ (b) $\hat{E} = i\hbar\frac{\partial}{\partial t}$
   (c) $\hat{E} = \hbar\frac{\partial}{\partial t}$ (d) $\hat{E} = -\frac{1}{i\hbar}\frac{\partial}{\partial t}$.

   (iii) The effective mass of an electron in a crystal is given by
   (a) $\frac{h^2}{d^2E/dk^2}$ (b) $h^2\frac{d^2E}{dk^2}$ (c) $\frac{1}{h^2}\frac{d^2E}{dk^2}$ (d) none of these.

   (iv) The waves representing a free particle in space are
   (a) standing waves (b) progressive waves
   (c) transverse waves (d) longitudinal waves.

   (v) In a p-type semiconductor, the donor level
   (a) lies near the valence band edge
   (b) lies near the conduction band edge
   (c) lies halfway between the valence band and conduction band edges
   (d) does not exist.

   (vi) The unit of Planck's constant is the same as that of
   (a) linear momentum (b) angular momentum
   (c) work (d) torque.

(vii) The Lagrangian of a system is a function of

(a) $(q_j, \dot{q}_j, t)$ (b) $(q_j, \dot{p}_j, t)$
(c) (q_j, p_j, t) (d) $(\dot{q}_j, \dot{p}_j, t)$

(viii) For an ideal gas molecules, the ratio of $v_{rms}: v_{avg}: v_{mp}$ is

(a) $\sqrt{\frac{8}{\pi}}: \sqrt{2}: \sqrt{3}$ (b) $\sqrt{2}: \sqrt{\frac{8}{\pi}}: \sqrt{3}$ (c) $\sqrt{3}: \sqrt{2}: \sqrt{\frac{8}{\pi}}$ (d) $\sqrt{\frac{\pi}{8}}: \sqrt{2}: \sqrt{\frac{1}{3}}$

(ix) If N is the number of atoms per unit volume in a dielectric, the relationship between the atomic polarizability α and the electric susceptibility χ is given by

(a) $\chi = \frac{N\alpha}{\varepsilon_o}$ (b) $\chi = N\alpha\varepsilon_0$ (c) $\alpha = \frac{N_\chi}{\varepsilon_0}$ (d) $\alpha = N_\chi \varepsilon_0$

(x) The number of meaningful ways in which 4 fermions can be arranged in 5 compartments is

(a) 1 (b) 4 (c) 5 (d) 9.

Group – B

2. (a) State the nature of constraint and enumerate the degrees of freedom in each of the following cases:
i) a simple pendulum with rigid support.
ii) a particle sliding down an inclined plane under the influence of gravity.

(b) Consider a simple pendulum with a mass m and string length l. Obtain Hamilton's equations of motion for this system.

(c) Show that if a generalized coordinate is cyclic in the Lagrangian, then the corresponding generalized momentum is conserved.

(d) Write down the time-independent Schrödinger equation in one dimension, and define all the terms. What is the physical interpretation of the wave function?

(1.5 + 1.5) + 4 + 2 + (2 + 1) = 12

3 (a) The potential energy of a quantum particle confined within one-dimension is

$$V(x) = 0, for\ 0 < x < L$$
$$= \infty, for\ x \le 0; x \ge L.$$

Show that the energy of this particle is quantized.

(b) For the above mentioned system, show that $\langle x \rangle = \frac{L}{2}$ for ground state.

(c) Evaluate the commutator $[\hat{x}, \hat{p}_x^2]$

(d) What is the probability current density for the wave function $\varphi(x) = Ae^{ikx}$?

4 + 3 + 3 + 2 = 12

Group – C

4. (a) Compare Maxwell-Boltzmann (MB), Fermi-Dirac (FD), and Bose-Einstein (BE) statistics mentioning at least three characteristics.

(b) Four particles are distributed into three energy levels having energies *0*, *E*, *3E* so that the total energy of the system is 4*E*. If the levels are degenerate with degeneracy 2, 2, and 3 respectively, write down the macrostates and the number of the corresponding microstates if the particles obey (i) MB statistics, (ii) FD statistics.

(c) (i) Write down the Fermi-Dirac distribution function. (ii) Plot it against energy for $T = 0\ K$ and for $T > 0\ K$ where T is the temperature. (iii) Evaluate the Fermi-Dirac distribution function at an energy kT above the Fermi energy, where k is the Boltzmann constant.

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

5. (a) Find out the expression of most probable speed [v_{mp}] and average speed [V_{ave}] of ideal gas molecules. Given that

$N(E)dE = \left[\frac{2\pi N}{(\pi KT)^{\frac{3}{2}}}\right] e^{-\frac{E}{KT}} E^{\frac{1}{2}} dE$, where symbols have their meaning.

(b) Obtain Planck's formula for black body radiation using BE statistics.

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

(2 + 2) + 4 + 4 = 12

Group – D

6. (a) A parallel plate capacitor (plate area, $A = 5 \times 6\ cm^2$, distance between the plates, $d = 1.5\ mm$) is filled with a dielectric (of dielectric constant = 5) and is connected to a 100 volt battery. Calculate (i) the capacitance of the capacitor, (ii) the electric field between the plates, (iii) the magnitude of the total free charge on each plate, and (iv) the magnitude of the polarized charge in the dielectric associated with each plate. ($\varepsilon_0 = 8.85 \times 10^{-12} C^2/Nm^2$)

(b) Using a simple spherical model for an atom, show that the electronic polarizability is proportional to the atomic volume.

(c) The electric susceptibility of carbon dioxide (CO_2) is 0.985×10^{-3}. Calculate its polarizability if its density is 1.977 kg/m^3. (Molecular weight of $CO_2 \approx 44$ *gram/mole*, Avogadro number = 6.023×10^{23})

(1 + 1 + 1 + 1) + 5 + 3 = 12