2015

PHYSICS II

(PHYS 2001)

Time Alloted : 3 Hours *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 alternatives for the following : **[10×1=10]**

   i) A particle of mass m is sliding without friction down an inclined plane (angle of inclination is α). Considering x to be the generalized coordinate, the Lagrangian of the system can be represented as

   (a) $L = \frac{1}{2}mx^2 - mg\sin\alpha$ (b) $L = \frac{1}{2}mx^2 - mg\cos\alpha$

   (c) $L = \frac{1}{2}mx^2 + mg\sin\alpha$ (d) $L = \frac{1}{2}mx^2 - mg\cos\alpha$

ii) The width of energy band depends on

(a) the extent of overlap of wave function ψ_1 and ψ_2 corresponding to the two atoms

(b) the interaction between the two atoms

(c) both (a) and (b)

(d) none of these

iii) The statistics obeyed by $_2He^4$ atom is

(a) MB statistics (b) BE statistics

(c) FD statistics (d) BE and FD statistics

iv) In intrinsic semiconductor the carrier concentration varies as

(a) T^{-1} (b) T^2

(c) $T^{3/2}$ (d) T

where T is temperature

v) "Some crystalline solids exihibit electric polarization when strained elastically." This is known as

(a) ferromagnetic effect (b) Anti-ferroelectric effect

(c) piezoelectric effect (d) hysteresis

vi) In superconducting state of a substance which of the following is correct

(a) $E \neq 0, B \neq 0$ (b) $E = 0, B \neq 0$

(c) $E \neq 0, B = 0$ (d) $E = 0, B = 0$

vii) A system is called strongly degenerated if

(a) $\frac{n_i}{g_i} = 1$ (b) $\frac{n_i}{g_i} >> 1$

(c) $\frac{n_i}{g_i} << 1$ (d) $g_i = 1$

where n_i is the number of particles and g_i is the number of states in the ith energy level.

viii) If the Lagrangian of a system is cyclic in one coordinate then the corresponding conserved quantity is

(a) energy
(b) force
(c) momentum
(d) Hamiltonian function of the system

ix) The susceptibility of an anti ferromagnetic material is given by

(a) $\chi = \frac{C}{T+\theta}$ (b) $\chi = C(T+\theta)$

(c) $\chi = \frac{C}{T-\theta}$ (d) $\chi = \frac{C}{\theta - T_c}$

x) The magnitude of induced dipole moment of an orbiting electron in presence of an external magnetic field is

(a) $\frac{e^2r^2B}{4m}$ (b) $\frac{e^2B}{4mr^2}$

(c) $\frac{e^2Bm}{4\pi r^2}$ (d) $\frac{e^2B}{4\pi r^2}$

where the terms have their usual meaning.

GROUP - B

2. (a) For a system of two masses (m_1 and m_2 such that $m_1 > m_2$) connected by an inextensible string passing over a small smooth pulley,

(i) state the nature of the constrain(s) involved in the system.

(ii) how many degrees of freedom does the system have?

(iii) write the Lagrangian of the system.

(b) Show that $\psi(x) = Ae^{ix}$ and $\psi(x) = Ae^{-ix}$ are degenerated wave functions.

(c) The Lagrangian of a particle of mass m in one dimension is given by $L = \frac{1}{2}m(x^2 - \omega^2x^2)e^{bt}$. Obtain the canonical momentum and equation of motion following Lagrangian method. What type of motion is the particle undergoing?

(d) Consider the wave function $\psi(x) = Ae^{-\frac{x^2}{a^2}}e^{ikx}$ where A is real constant. Find the value of A.

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

3. (a) A free particle of mass m is confined within x = 0 and x = L,

(i) write down the Schrodinger time independent equation for such a system.

(ii) solve the equation to find out the eigen function.

(iii) find the maximum probability of finding the particle within the region of particle confinement in the ground level.

(b) Prove that for a conservative system, the Hamiltonian represents the total energy of the system.

(c) Show that if a given coordinate is cyclic in Lagrangian, it will also be cyclic in Hamiltonian.

(d) The energy eigen value and the corresponding eigen function for a particle of mass *m* in an one-dimensional potential V(x) are E = 0 and $\psi(x) = \frac{A}{x^2 + a^2}$ respectively. (A is a constant). Determine the potential V(x)

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

GROUP - C

4. (a) Define macrostate and microstate of a thermodynamic system.

   (b) 3 distinguishable particles, each of which can be in one of the $\varepsilon, 2\varepsilon, 3\varepsilon, 4\varepsilon$ non degenerate energy states, have total energy 6ε.

   (i) Find all possible distributions of particles in the energy states.

   (ii) Find the number of microstates in each case.

   (iii) Find the most probable state.

   (c) Derive Planck's radiation law from Bose-Einstein statistics. **2+(2+4+1)+3 = 12**

5. (a) In how many ways 2 indistinguishable particles can be distributed in three distinct states, if the particles obey (i) F–D statistics, (ii) B–E statistics?

   (b) Plot electron distribution function governed by Fermi-Dirac statistics in metal at T = 0K and T > 0K. Explain their physical significance.

   (c) Calculate using Fermi-Dirac distribution the concentration of electron in the conduction band of a semiconductor. **(2+2)+(2+2)+4 = 12**

Group - D

6. (a) Define dielectric constant. Show that for an isotropic dielectric the expression for dielectric constant is $k = 1+\chi_e$ where χ_e is the susceptibility of the dielectric material.

   (b) Assume that an electron of charge (–e) revolves round a nucleus of an atom with an angular velocity ω.

   (i) Determine the magnetic dipole moment due to the motion of the electron.

   (ii) How is this magnetic moment related to orbital angular momentum of the electron?

   (iii) How is Bohr magneton derived from the expression of magnetic moment of the electron?

   (c) Assuming that the electric polarizability of an argon atom is 1.43×10^{40} Fermi $-m^2$, find the dielectric constant of solid Argon. Given density of Argon is 1.8 gm – cm^{-3} and atomic mass of Argon is 39.95 gm/mol.

   (d) For a magnetic material find the relation between relative permeability and susceptibility.

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

7. (a) Define displacement vector $\vec{D}$. Show that for an isotropic di-electric $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$ where $\vec{P}$ is the polarization vector.

   (b) Dielectric constant of a gas at NTP is 1.00074. Calculate the dipole moment of each atom of the gas when it is held in an external field of 3×10^4V/m.

   (c) What do you mean by hysteresis loop? How will you determine the value of remanance and coercivity from a loop.

   (d) Write three differences between hard and soft magnetic materials. **(1+2)+2+(2+2)+3 = 12**

GROUP - E

8. (a) Write the Schrodinger wave equation for an electron moving in one-dimensional periodic potential..

   (b) State Bloch theorem. What is Bloch function?

   (c) What is effective mass of an electron?

   (d) Discuss the effect of magnetic field on superconductivity.

(e) For a superconductor sample the critical fields are respectively 1.4×10^5 and 4.2×10^5 A/m for 14K and 13K. Calculate the transition temperature and critical fields at 0K and 4.2K.

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

9. (a) What is Meissner effect? Show that a superconducting material behaves as a perfect diamagnetic material below its transition temperature.

(b) Explain the concept of conduction band, Valence band and forbidden energy gap.

(c) Show that a superconducting specimen have finite current density in absence of electric field.

(d) Prove that velocity of a free electron moving in a crystal lattice is directly proportional to wave vector k.

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