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B.Tech/EE/IT/ME/ 3rd Sem/ PHYS-2001/2016

2016

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 x 1=10]**

i) The generalized force is related to potential energy through which of the following relations?

a) $Q_j = \frac{\partial V}{\partial q_j}$ b) $Q_j = \frac{-\partial V}{\partial q_j}$ c) $Q_j = \frac{\partial q_j}{\partial v}$ d) $Q_j = \frac{-\partial q_j}{\partial v}$

ii) If $\hat{x}$ is the position operator and $\widehat{p_x}$ (= -iħ $\frac{\partial}{\partial x}$) is the corresponding momentum operator, then the commutator [$\hat{x}$, $\widehat{p_x}$] is represented by

a) - iħ b) iħ c) $\frac{1}{\hbar}$ d) zero

iii) The group velocity of an electron in a crystal lattice is $\vartheta = \alpha \frac{k^3}{3}$, where k is the wave number. It's effective mass is

a) $\frac{h}{\alpha k^3}$ b) 0 c) ∞ d) $\frac{h}{\alpha k^2}$

iv) The expectation value of the position of a particle confined in one dimensional potential box of length L in the ground state is

a) L/4 b) L/3 c) L/2 d) 0

v) Which of the following particle is NOT a Boson ?

a) Photon b) Alpha-particle c) Neutron d) Meson

vi) The dielectric constant ε_r and the electric susceptibility χ are related through

a) $\chi = \varepsilon_r - 1$ b) $\chi = \varepsilon_r + 1$ c) $\chi = 1 - \varepsilon_r$ d) none of these

vii) The Curie Law in paramagnetic materials gives the susceptibility as

a) $\chi = CT$ b) $\chi = C/T$ c) $\chi = T/C$ d) $\chi = C/(T - \theta)$

viii) A free particle has the wave function $\psi(x) = Ae^{ikx}$. Its momentum is given by

a) $k/\hbar$ b) $\hbar/k$ c) $\hbar k$ d) none of these

ix) In an intrinsic semiconductor, the donor level

a) lies near the valence band edge

b) lies near the conduction band edge

c) lies about halfway between the valence and conduction band edges

d) does not exist

x) A system is called strongly degenerate if

a) $\frac{n_i}{g_i} = 1$ b) $\frac{n_i}{g_i} >> 1$ c) $\frac{n_i}{g_i} << 1$ d) $g_i = 1$

GROUP - B

2 a) What are generalized coordinates ? Suppose a system contains N free particles. How many generalized coordinates will this system have? What is this number for a simple pendulum? Explain your answers.

b) The kinetic and potential energies of a system are given respectively by $T = \frac{1}{2} m\dot{x}^2$ and $V = \frac{1}{2} kx^2$ where m and k are constants. Construct the Lagrangian. Find the expressions for the generalized momentum and generalized force for this system. Derive the equation of this system.

c) Show that in case of a quantum system then eigen functions corresponding to two different eigen values are orthogonal to each other.

d) Why do you think that the operators in quantum mechanics must be Hermitian in nature?

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

3 a) If the Lagrangian of a system is explicitly independent of time, show that the Hamiltonian of the system is conserved.

b) The wave function of a quantum mechanical particle is given by $\psi(x) = A \sin(\frac{\pi x}{L})$ for $0 \leq x \leq L$

$= 0$ otherwise

Determine the value of *A*. Also find the expectation values of the position and the momentum of the particle.

c) Show that $[\hat{x}, \hat{L}_y] = i\hbar z$, for a quantum mechanical system, where the terms have their usual meaning.

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

GROUP - C

4 a) Draw graphs of the Maxwell- Boltzmann, Bose-Einstein and Fermi-Dirac distribution functions in the same plot as a function of the dimensionless quantity $(E-\mu)k_BT$ where E is the energy, μ is the chemical potential, k_B is the Boltzmann constant and T is the temperature.

b) Derive Planck's radiation law from Bose-Einstein statistics. State clearly the assumptions made in the theory.

c) Calculate using Fermi- Dirac statistics the concentration of electron in the conduction band of a semiconductor.

d) The electron concentration of silver is 1.38×10^{-23} m^{-3}. Find its Fermi energy.

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

5 a) Three particles are to be distributed in 4 non-degenerate states with energies 0 eV, 1eV, 2eV and 3eV. If the total energy of the system is 6eV, write down all possible microstates and macrostates for the particles if they obey
i) Maxwell-Boltzmann statistics; ii) Bose-Einstein statistics. What are the most probable macrostates in each case?

b) Derive expression for the mean energy per electron at absolute zero of temperature for a free electron gas in a metal. Express your answer in terms of the Fermi energy of the metal.

c) Write down the expressions of the concentrations of electrons and holes in the conduction and valence bands respectively of a semiconductor. Hence find the location of the Fermi level in an intrinsic semiconductor relative to the conduction and valence band edges.

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

GROUP - D

6 a) Derive an expression for the capacitance of a parallel plate capacitor containing a dielectric.

b) Write the differences among dia, para and ferro-magnetic materials on the basis of magnetic moment.

c) Why do we use ferrite material in radios and other communication equipment?

d) Define magnetic field intensity $\vec{H}$. Show that for a linear magnetic material, $\vec{B} = \mu \vec{H}$ where μ is the permeability of the material.

4+3+2+(2+1)=12

7 a) Show that electronic polarizability α_e is given by

$\alpha_e = \frac{\epsilon_0 (\epsilon_r - 1)}{N}$ where the symbols have their usual meaning.

b) Define the elctric displacement vector $\vec{D}$. Show that for an isotropic dielectric, the displacement vector is related to the electric field $\vec{E}$, through $\vec{D} = \epsilon_0 \epsilon_r \vec{E}$ where ϵ_0 and ϵ_r are the permittivity of free space and the dielectric constant of the dielectric respectively.

c) State Weiss' hypothesis for ferromagnetic materials and hence derive the Curie-Weiss law.

d) What do you mean by hysteresis loss of magnetic material?

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

GROUP - E

8 a) State Bloch's theorem. What is the Bloch function?

b) What do you mean by critical magnetic field in terms of super conducting material? How does critical magnetic field vary with temperature? Write down the expression explaining the terms.

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

d) What is the effective mass of an electron? If the group velocity of an electron moving in a 1D crystal is given by "$a+bk^3$", find out the effective mass of the electron. Here "k" is the wave number and a, b are positive constants.

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

9 a) An electron is moving in a 1D periodic lattice with lattice constant "a". If "H" be the Hamiltonian of the electron and "T" be the lattice translation operator, then show that if "f(x)" is an Eigen function of "H", then "Tf(x)" is also an Eigen function of "H" corresponding to the same energy value.

b) Discuss the formation of Brillouin zones for a linear lattice.

c) Define London penetration depth. Derive the London equations and discuss how they explain Meissner effect and flux penetration?

d) Calculate the critical magnetic field of lead at 4.2K. (given Lead has critical temperature 7.18K and has critical magnetic field at 0K is 6.51×10^4 A/m)

3+2+(1+4)+2=12