B.TECH/AEIE/ECE/CSE/2nd Sem/PHYS-2001/2016

2016

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) The Lagrangian of a system is given in terms of the coordinates r, θ, φ and the corresponding velocities as $L = \frac{1}{2}\alpha\dot{\theta}^2 + \frac{1}{2}r^2\dot{\varphi}^2 + \frac{1}{2}\beta\dot{\gamma}^2$, α and β are constants. The cyclic coordinates are

   (a) γ and θ   (b) γ and φ

   (c) θ and φ   (d) γ, θ, and φ

ii) The total polarization of a polyatomic gas is

(a) $\vec{P} = N(\alpha_e + \alpha_i)\vec{E}$ (b) $\vec{P} = N(\alpha_e + \alpha_i + \frac{\mu}{KT})\vec{E}$

(c) $\vec{P} = N(\alpha_e + \alpha_i + \frac{\mu^2}{3KT})\vec{E}$ (d) $\vec{P} = N\frac{\mu}{KT}\vec{E}$

iii) For four distinguishable particles for macrostates (3,1) the number of possible arrangements are

(a) 2 (b) 3

(c) 4 (d) 9

iv) The average energy of a free electron in a metal (with Fermi level E_F) at T. = 0 K is given by

(a) zero (b) $\frac{1}{2}E_F$

(c) $\frac{3}{5}E_F$ (d) E_F

v) Which of the following particles is NOT a Fermion?

(a) Proton (b) Alpha-particle

(c) Neutron (d) Electron.

vi) Given $\phi = C_1\phi_1 + C_2\phi_2$, where ϕ_1 and ϕ_2 are orthonormal energy eigen states of a system corresponding to energies E_1 and E_2. If ϕ is normalised and $C_1 = \frac{1}{\sqrt{3}}$ then C_2 is

(a) $\frac{1}{\sqrt{3}}$ (b) $\frac{2}{\sqrt{3}}$

(c) $\sqrt{\frac{2}{3}}$ (d) $\sqrt{\frac{3}{2}}$

$C = \frac{q}{A\epsilon_0}$

vii) If the constraint relations can be made independent of velocity, then the constraints are called

(a) Scleronomic (b) Conservative

(c) Bilateral (d) Holonomic

viii) Dielectrics are substances which are

(a) semiconductors (b) conductor

(c) insulators (d) none of these

ix) In an intrinsic semiconductor, the donor level is

(a) near the valence band edge

(b) near the conduction band edge

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

(d) none of the above

x) A superconductor below its transition temperature behaves like a

(a) paramagnetic material

(b) diamagnetic material

(c) antiferromagnetic material

(d) ferromagnetic material

GROUP - B

2. (a) Write down the Lagrangian function and Langrangian equation of motion of a freely falling body falling from a height 'h'.

(b) For a free particle moving with relativistic speed, has mass $m = \dfrac{m_0}{\sqrt{1-\dfrac{v^2}{c^2}}}$ where m_0 is the rest mass, v is the generalised velocity and c is the speed of light in vacuum. Assuming the langrangian of the system to be $L = -m_0c^2\left(1-\dfrac{v^2}{c^2}\right)^{\frac{1}{2}}$, obtain momentum of the particle.

(c) Verify that the quantum mechanical operators x and p_x satisfy the equation $x\,p_x - p_x\,x = i\hbar$. Hence show that $[x, p_x^n] = n\,i\hbar\,p_x^{n-1}$.

(d) Write down the expression for energy eigein value for three dimensional potential well. Hence show that the first excited state has three fold degeneracy.

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

3. (a) What are the necessary conditions for Hamiltonian H to represent the total energy of the system?

(b) Obtain the Hamiltonian function from its Lagrangian for a particle of mass m and undergoing simple harmonic vibration. Hence obtain corresponding Hamiltonian equation of motion.

(c) Show that the probability current density for free particle is proportional to its velocity.

(d) A normalised wave function is given by,

$$\psi(x) = \left(\frac{1}{\sigma\sqrt{\pi}}\right)^{\frac{1}{2}} e^{\frac{-x^2}{2\sigma^2}}$$

Calculate <x>.

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

GROUP - C

4\. (a) Show that both FD and BE statistics approach M-B statistics at a certain limit.

(b) Show that the average kinetic energy per electron gas at 0K is $\bar{E}_0 = \frac{3}{5} E_{F(0)}$ where $E_{F(0)}$ is the Fermi energy at 0K.

(c) If v_p, $\bar{v}$ and $v_{r.m.s}$ stand respectively for most probable, average and root-mean square speeds, show that for the Maxwellian distribution,

$$v_p = \frac{\bar{v}}{\sqrt{4/\pi}} = \frac{v_{r.m.s}}{\sqrt{3/2}}$$

(d) Calculate using Fermi-Dirac distribution the concentration of holes in the valance band of a semiconductor.

2+3+3+4 = 12

5\. (a) Show that in case of an intrinsic semiconductor the Fermi level is located half way between the valance band and conduction band.

(b) Using Fermi-Dirac distribution, obtain the expression for the Fermi energy $E_{F(0)}$ for electrons in a metal at 0K.

(c) Calculate the Fermi temperature and Fermi velocity for sodium whose Fermi level is 1.6 eV.

(Given, Boltzlann constant = 1.38×10^{-23} JK^{-1}; mass of electron = 9.1×10^{-31} kg.)

(d) Differentiate among MB statistics, FD and BE statistics in terms of nature of particles to which they are applicable; restriction of number distribution in different energy states and mathematical expression of probability distribution function.

2+4+3+3 = 12

[Turn over]

Group - D

6. (a) Consider a parallel plate capacitor without dielectric with its plates having equal and opposite charges. The capacitor is not connected to any circuit. What is the electric field (E_0) between the plates of the capacitor? Now insert a dielectric between the plates so that it completely fills the region between the plates. Derive an expression for the electric field between the plates in the presence of the dielectric and express it in terms of E_0.

(b) Derive an expression for the electronic polarizability using a simple spherical model of an atom.

(c) Consider a gas of polar molecules where the magnitude of the permanent dipole moment per molecule is 1 D. Calculate the field strength required at T = 297 K so that the average induced dipole moment per molecule is 0.07 times the saturation value.

(d) What is the physical significance of the Bohr magneton? Estimate its value.

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

7. (a) Calculate the induced dipole moment per unit volume of He gas if it is placed in an electric field of 6000 V/cm. The atomic polarizability of He is 0.18×10^{-40} F-m^2 and the gas density is 2.6×10^{25} atoms per m^3.

(b) Write down the general expression for the average induced magnetic moment per atom in a paramagnetic material in presence of a magnetic field. Use this expression to derive Curie's Law.

(c) Draw the graphs of the reciprocals of the magnetic susceptibility against temperature for paramagnetic, ferromagnetic and antiferromagnetic materials in the same plot.

$$\frac{F m^2 V^6 m^3 N m^2}{m . c^2}$$

(d) The magnetic susceptibility of Ge is -0.8×10^{-5}. Given that the applied magnetic field intensity is 5×10^{4} Amp/m, calculate the magnetization in Ge and also the magnetic field induction.

(e) Draw the hysteresis loops of a soft and a hard magnetic material in the same plot.

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

GROUP - E

(a) State and explain Bloch's theorem.

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

(i) Find the expression for the velocity of the electron as a function of k. For what value of k the velocity is maximum?

(ii) Find the difference between the top and the bottom of the energy band.

(iii) Find the expression for the effective mass of the electron as a function of k. What are its values at the top and the bottom of the energy band?

(c) What is the Meissner effect? Illustrate your answer with an appropriate diagram.

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

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$

$\frac{N.m^2}{C^2} = \frac{C^2}{Nm^2}$

9. (a) An electron is moving in one dimension in a region where the potential is given by $V(x) = V_0\left[1+\cos\left(\frac{2\pi x}{a}\right)\right]$ where V_0 and a are constants. Show that if $\psi(x)$ is an eigenfunction of the Hamiltonian then $\psi(x + a)$ is also an eigenfunction of the Hamiltonian with the same energy.

(b) Write a short note on Type 1 and Type 2 superconductors explaining their difference.

(c) What is the London penetration depth? Write down its expression as a function of temperature.

(d) Calculate the number density of electrons in a material for which London penetration depth at zero K is 0.5×10^{-8} m. ($\mu_0 = 4\pi \times 10^{-7}$ N/A^2).

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

$B = \mu_0 J$

$\nabla B = \mu_0 \nabla \times J$

$\nabla B = \mu_0 \frac{ne^2}{m} B$

$\frac{\mu_0 n e^2}{m} B$

$\lambda = \sqrt{\frac{m}{\mu_0 n e^2}}$

$B_0 e^{-x/\lambda}$