2024
M.Sc.
Second Semester
CORE – 08
PHYSICS
Course Code: MPHC 2.41
(Condensed Matter Physics - I)

Total Mark: 70 *Pass Mark: 28*
Time: 3 hours

Answer five *questions, taking* one *from each unit.*

UNIT–I

1. (a) Derive the dispersion relation for one-dimensional monatomic lattice. 10

   (b) Determine the phase velocity and group velocity of the wave motion along a one-dimensional lattice. What happens to the group velocity when $ka = \pm\pi$? 2

   (c) The elastic stiffness constant for sodium chloride is 5×10^{10} N/m^2. What is the value of the force constant and the frequency for the crystal?
   Given: Lattice constant for NaCl crystal = 5.5 Å,
   Mass of Na atom = 23 amu, Mass of Cl atom = 35.5 amu and
   1 amu = 1.66×10^{-27} kg. 2

2. (a) Derive an expression for lattice specific heat capacity following Einstien model. Discuss the temperature dependence of lattice heat capacity and compare with expiremental observations. 9

   (b) Clearly discuss the electronic specific heat of solid. 5

UNIT–II

3. (a) Using Kronig-Penny model, show that the energy spectrum of an electron consists of a number of allowed energy bands separated by forbidden regions. 10

(b) The energy wave vector dispersion relation for a one-dimentional crystal of lattice constant a is given by $E(k) = E_0 - \alpha - 2\beta \cos ka$, where E_0, α, β are constants. Obtain the effective mass of the electron at the bottom and at the top of the band. 4

4. (a) Distinguish metals, semiconductor and insulator in view of band theory of solids. Explain why the conductivity of metal decreases while that of the semiconductor increases with the rise of temperature. 10

(b) If the energy near the valence band of a crystal is given by $E = -Dk^2 (D = 10^{-39} \text{Jm}^2)$. An electron with wave vector $\vec{k} = 10^{10} k_x \text{m}^{-1}$ is removed from an orbital in the completely filled valence band. If the effective mass of the hole is $m_h^* = 5.5 \times 10^{30} \text{kg}$, determine the velocity, momentum and energy of the hole. 4

UNIT–III

5. Discuss the theory of generation and recombination of charge carriers. If the resistivity of an intrinsic semiconductor is $4.5\,\Omega\text{m}$ at 20° C and $2.0\,\Omega\text{m}$ at 32° C. Find the energy band gap. 8+6=14

6. Discuss Hall effect in details. A semiconducting crystal 12 mm long, 5 mm wide has a magnetic flux density of 0.5 Wb/m^2 applied from front to back perpendicular to largest faces. When a current of 20 mA flows lengthwise through the specimen, the voltage measured across its width is found to be $37\,\mu\text{V}$. Find the Hall coefficient of the conductor. 10+4=14

UNIT–IV

7. Deduce an expression for the electronic polarizability of an atom on the basis of classical theory. If the relative permittivity and square of refractive index of a dielectric material are 4.94 and 2.69 respectively. Find the ratio between electronic and ionic polarizability of the material. 10+4=14

8. Derive the London equation and discuss how does it help in explaining the superconducting state. If the critical fields for a sample are 1.4×10^5 A/m at T = 14 K and 13 K respectively. What are the transition temperatures and critical field at 0 K and 4.2 K? 10+4=14

UNIT–V

9. (a) Discuss Langevin's classical theory on diamagnetism in details. 10
   (b) An atom with L = 2 and 0 spin angular momentum is placed in a uniform magnetic field of induction 2 Wb/m^2. Calculate the rate of precession of the resultant magnetic moment. Also calculate the corresponding linear frequency and the radius of an electron in the ground state. 4

10. (a) Give an account of Weiss theory of ferromagnetism. Discuss the temperature variation of saturation magnetization . 10

    (b) Calculate
    (i) the intrinsic flux density near 0 K and
    (ii) the ratio of magnetization at 300 K in the pesence of an external field of 1 mT to the spntaneous magnetization at 0 K of a ferromagnetic material. Given: $J = \frac{3}{2}$ and $g = 2$; Curie temperature $T_c = 125\,\text{K}$. 4