2023

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 vibrational modes of a diatomic linear lattice. 7

   (b) Name the different branches of the dispersion relation curve. What is the difference between the two branches? 7

2. (a) Give the Debye's theory of specific heat of a crystalline solid and show that in suitable limits, it gives Dulong and Petit's law and the T^3-law. 10

   (b) If Einstein's temperature of a material is 157 K, find the value of C_v for the material at 100 K in cal/mol/K using Einstein's formula. Also, calculate Einstein's frequency. 4

UNIT–II

3. (a) Show that the effective mass of an electron is inversely proportional to the second derivative of the (E-K) curve. Discuss the condition when the effective mass of an electron becomes positive, negative and infinity. 10

   (b) The energy near a valence band edge is given by $E(k) = -1\times10^{-26}k^2$ ergs. An electron is removed from the orbital $= 1\times10^{7}\,k_x\,\text{cm}^{-1}$. The band is otherwise full. Give the sign and magnitude of the effective mass of the hole. 4

4. (a) Discuss the tightly binding approximation of a solid. 10

(b) Find the lowest energy band using Kronig-Penney model for $P \ll 1$. 4

UNIT–III

5. (a) Deduce the expression for the concentration of electrons of an intrinsic semiconductor. Show that the product of concentration of electron in the conduction band (n) and that of holes in the valence band (p) of a semiconductor depends upon the energy gap. 8+3=11

(b) Compute the concentration of intrinsic charge carriers in a germanium crystal at 300 K. Given that E_g= 0.72 eV and assume $m_e^* = m_e$. 3

6. (a) Obtain an expression for carrier concentration in an n-type extrinsic semiconductor. Discuss the variation in the position of Fermi level with temperature in an n-type semiconductor. 8+3=11

(b) In a doped semiconductor, there are 4.52×10^{24} holes and 1.25×10^{14} electrons per cubic meter. What will be the carrier density in undoped specimen? Electron and hole mobilities are 0.38 $m^2/V.s$ and 0.18 $m^2/V.s$. Calculate the conductivity of intrinsic and the doped semiconductor. 3

UNIT–IV

7. (a) Deduce an expression for the oriental polarizability per molecule of a gas of polar substance at temperature T. (Assume that $pE / KT \ll 1$, where p is the dipole moment of the polar molecule and E is the magnitude of the applied electric field.) 10

(b) The crystal of NaCl has a static dielectric constant of 5.6 and optical index of refraction 1.5. Calculate the percentage contribution of ionic polarizability. 4

8. (a) Discuss dipole theory of ferroelectricity. What are the essential properties of the ferroelectric crystals? 8+3=11

(b) A solid dielectric has electronic polarizability of 10^{-40} Fm^2. If the internal electric field be a Lorentz field, what is the dielectric constant of the material? [Given: density = 3×10^{28} atoms/m^3] 3

UNIT–V

9. (a) Deduce Langevin's classical theory on paramagnetic susceptibility. 12

(b) A paramagnetic material has a magnetic field intensity of 10^4 A/m. If the susceptibility of the material at room temperature is 3.7×10^{-3}, calculate the magnetization and flux density of the material. 2

10. (a) Describe the two-sub lattice model to explain antiferromagnetism. How does this model account for the difference between the Neel temperature (T_N) and Curie-Weiss temperature (θ)? 12

(b) Calculate the change in magnetic moment of a circulating electron in an applied field of 2 T acting perpendicular to the plane of the orbit. [$r = 5.29\times10^{-11}$ m for the radius of the orbit] 2