May 2025
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) Obtain the dispersion relation of a diatomic linear lattice and discuss the nature of the acoustic and optical branches. What is the difference between the two branches? 12
   (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

2. (a) Discuss 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) Show that in the Debye approximation, the total zero-point energy per gm-mol of a solid is given by $\frac{9}{8}R\theta_D$. 4

UNIT–II

3. (a) What do you mean by effective mass of an electron? What is its significance? Show that the effective mass of an electron is inversely proportional to the second derivative of the (E-K) curve. 12
   (b) An insulator has an optical absorption which occurs for all wavelengths shorter than 1800 Å. Find the width of the forbidden energy band for this insulator. 2

4. (a) What are the differences between nearly free electron approximation and tightly binding approximation? Find the lowest energy band using Kronig-Penney model for $P \ll 1$. 10

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

UNIT–III

5. (a) Deduce expression for the concentration of electrons of an intrinsic semiconductor. What is the law of mass action? What is its significance? 12

(b) Calculate the resistivity of Ge at room temperature from the following data: Intrinsic carrier density of Ge at $RT = 2.37\times10^{19}$/m^3. The electron mobility $\mu_e = 0.38$ m^2/V/s. The hole mobility $\mu_h = 0.18$ m^2/V/s. 2

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. 12

(b) Calculate the intrinsic carrier density and conductivity at 300 K in Germanium. (Given: Atomic weight of Ge = 72.6, density of Ge = 5400 Kg/m^3, mobility of electrons $\mu_e = 0.4$ m^2/V/s, mobility of holes $\mu_h = 0.2$ m^2/V/s, and band Gap of Ge $E_g = 0.7$eV) 2

UNIT–IV

7. (a) Deduce an expression for the oriental polarizability per molecule of a gas of polar substance at temperature *T*. Discuss the Clausius-Mossotti relation for an isotopic dielectric. 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 in detail about Meissner effect and fluxoid. 12

(b) The diameter of a lead wire at 4.2 K is 1 mm. If the critical temperature for lead is 7.18 K and $H_o = 6.5\times10^4$ A/m, find the critical current. 2

UNIT–V

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

   (b) The magnetic field strength of a piece of metal is 10^6 A/m. Calculate the magnetization and flux density of the material. (Given: $\chi=1.5\times10^{-3}$) 2

10. (a) Describe the Heisenberg's exchange interaction. 6

    (b) Discuss the phenomenon of antiferromagnetism. 8