Phy
Solid State
14/10

QP Code : 12844

(2 ½ Hours) [Total Marks : 75

N.B. : (1) **All** questions are **compulsory**
(2) Figures to the **right** indicate **full** marks.
(3) Use of non-programmable **calculator** is allowed.
(4) Symbols have their usual meanings unless otherwise stated.

1. (a) Attempt any **one** : 10
(i) Explain relaxation time, collision time and mean free path as applied to free electrons in metals.
(ii) Derive an expression for density of energy states of a metal using Sommerfeld's model.

(b) Attempt any **one** : 5
(i) The Fermi temperature of copper is 8.18×10^4 K. Calculate the Fermi velocity of electrons in copper.
Given : $K_B = 1.38 \times 10^{-23}$ J/K
$m_e = 9.109 \times 10^{-31}$ kg.
(ii) Derive an expression for Fermi energy at absolute zero for a given metal in terms of the number of free electrons per unit volume.

2. (a) Attempt any **one** : 10
(i) Using E-K curves, derive an expression for effective number of electrons N_{eff} in an energy band of a crystal. Hence explain how band theory distinguishes between conductor, insulator and semiconductor.
(ii) What is Meissner effect in superconductor? Discuss type I and type II superconductor?

(b) Attempt any **one** : 5
(i) Consider a two dimensional square lattice of side 0.3 nm. At what electron momentum values do the sides of the first Brillouin zone come? What is the energy of the free electron with this momentum?
(ii) Explain how the superconducting transition temperature vary with magnetic field.

3. (a) Attempt any **one** : 10
(i) What is diamagnetism? Obtain an expression for the Larmor Frequency of precession of angular momentum vector about the direction of applied field. Hence derive an expression for diamagnetic susceptibility.
(ii) Discuss the quantum theory of Paramagnetism. Derive an expression for paramagnetic susceptibility at ordinary field strength and normal temperature.

(b) Attempt any **one** : 5
(i) Give the comparison of the Weiss molecular field theory with the experimental results in ferromagnetic materials.
(ii) Magnetic field strength in a material is 1200 A/m. If the magnetic susceptibility

of a material is - 5×10^{-6}. Calculate Magnetization (M) and magnetic flux density (B).

Given : $\mu_o = 4\pi \times 10^{-7}$ H/m

4. (a) Attempt any **one** : 10

(i) Set up the continuity equation for the charge carriers in a semiconductor.

(ii) Explain the various current components in a biased p-n junction. Derive an expression for the total current in a p-n diode as a function of the applied voltage.

(b) Attempt any **one** : 5

(i) Explain the Hall effect. State the expressions for the Hall voltage and Hall coefficient.

(ii) Find the forward current and static (dc) resistance of a p-n junction germanium diode if the temperature is 300 K and $I_o = 1\,\mu A$ for an applied forward bias voltage of 0.2V. Given : $e = 1.6 \times 10^{-19}$ C , $K_B = 1.38 \times 10^{-23}$ J/K

5 (a) Attempt any **one** : 4

(i) Discuss the variation of Fermi distribution function with temperature.

(ii) Calculate the electronic contribution to specific heat of copper using quantum formula at 300 k. Fermi energy of copper at 300 K is 7.05 eV.
Given : $K_B = 1.38 \times 10^{-23}$ J/K, $e = 1.6 \times 10^{-19}$ C , $N_A = 6.023 \times 10^{26}$ / kilo mole.

(b) Attempt any **one** : 4

(i) Discuss the conclusion of Kronig Penney model with the Scattering power P.
(a) $P \to 0$ (b) $P \to \infty$

(ii) The critical temperature for a superconductor is 6.4 K in Zero magnetic field. The critical magnetic field for the same material at 0 K is 7.5×10^4 A/m. Find the critical field at 3.6 K.

(c) Attempt any **one** : 4

(i) Calculate paramagnetic susceptibility at normal temperature for a substance having 6×10^{28} atom/m^3 and magnetic moment of each atom is 1.6×10^{-23} A.m^2
Given : $\mu_o = 4\pi \times 10^{-7}$ H/m, $K_B = 1.38 \times 10^{-23}$ J/k, $T = 300$K

(ii) Write a note on "Antiferromagnetism". 3

(d) Attempt any **one** :

(i) Find the diffusion coefficient of holes of a single crystal at 300 K, if the mobility of holes is 0.025 m^2 / V.S
Given : $e = 1.6 \times 10^{-19}$ C
$K_B = 1.38 \times 10^{-23}$ J/K

(ii) Explain qualitatively the formation of depletion layer at the junction at thermal equilibrium.
