(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) Derive an expression for density of energy states in metals, considering a particle in a three dimensional box.
(ii) Derive the Richardson-Dushmann equation for thermionic current density.
(b) Attempt any **one** : 5
(i) Discuss the failures of classical free electron theory in metals.
(ii) The density of silver is 10.5×10^3 kg/m^3. The atomic weight of silver is 108. Assuming that each silver atom provides one conduction electron, calculate the density of electrons. The conductivity of silver at 20°C is 6.8×10^7 mho/m. Calculate the mobility of electrons in silver.
Given : $N_A = 6.02 \times 10^{26}$ / kmol, $e = 1.6 \times 10^{-19}$ C

2. (a) Attempt any **one** : 10
(i) Discuss the Kronig-Penney model for the motion of an electron in a periodic potential. Hence explain importance of scattering power P.
(ii) Show that perfect diamagnetism and zero resistivity are two independent properties of superconductor.
(b) Attempt any **one** : 5
(i) Draw the first three Brillouin Zones for linear and two dimensional crystal lattice.
(ii) For a specimen of V_3 Ga, the critical fields are respectively, 1.4×10^5 and 4.2×10^5 amp/m. for 14 K and 13 K. Calculate the transition temperature and critical fields at 0K and 4.2 K

3. (a) Attempt any **one** : 10
(i) What is ferromagnetism? State assumptions of Weiss molecular field theory. Hence show that the ferromagnetic Curie temperature (θ_f) is proportional to the molecular field constant (γ).
(ii) Discuss classical Langevin theory of Paramagnetism. Derive an expression for paramagnetic susceptibility.
(b) Attempt any **one** : 5
(i) Write a note on 'Antiterromagnetism'.
(ii) A solid argon has atomic number 18 and concentration 2.66×10^8 atom/m^3 at 4 K. If the rms distance of an electron from the nearest nucleus is 0.62 A°. Calculate the magnetic susceptibility of argon.

[TURN OVER]

4. (a) Attempt any **one** : 10
   (i) Obtain an expression for concentration of electrons in an intrinsic semiconductor at temperature T K.
   (ii) Obtain an expression for contact potential difference at the open circuited p-n junction in terms of carrier concentrations under thermal equilibrium.

   (b) Attempt any **one** : 5
   (i) Mobilities of electrons and holes in a sample of intrinsic Ge at 300 K are 0.36 m^2/Vs and 0.17 $m^2/V.s$ respectively. If the conductivity of the specimen is 2.12 $ohm^{-1} m^{-1}$, then calculate the intrinsic carrier concentration. Given $e = 1.6 \times 10^{-19} C$
   (ii) Discuss the temperature dependence of forward Volt.-Amp. characteristics of a p-n junction diode.

5 (a) Attempt any **one** : 4
   (i) For sodium, $E_F = 3.2$ eV, calculate the Fermi temperature and Fermi velocity. $K_B = 1.38 \times 10^{-23}$ Joule/kelvin mass of the electron = 9.1×10^{-31} kg.
   (ii) State the assumptions made in quantum mechanical free electron theory.

   (b) Attempt any **one** : 4
   (i) Explain how band theory distinguishes between conductor, insulator and semiconductor.
   (ii) The critical magnetic field of a Superconductor is 4.5×10^3 A/m . Calculate the critical current which can flow through a long thin wire of the superconductor of diameter 10^{-3}m

   (c) Attempt any **one** : 4
   (i) Discuss the origin of ferromagnetic domains.
   (ii) Magnetic field strength in a diamagnetic material is 108 A/m. If its magnetic susceptibility is -0.6×10^{-5}. Calculate the magnetization and magnetic flux density.

   (d) Attempt any **one** : 3
   (i) For an intrinsic semiconductor with band gap energy 0.7 eV, determine the position of the Fermi level at 300 K if
   $m_n^* = 6\, m_e^*$
   $K_B = 1.38 \times 10^{-23}$ J/K
   (ii) Draw the energy band diagram for on open circuited p-n junction at equilibrium.
