($2\frac{1}{2}$ Hours) **Total Marks : 75**

N.B. : (1) **All** questions are **compulsory**.

(2) **Figures** to the **right** indicate **full** marks.

(3) Draw **neat** diagrams wherever **necessary**.

(5) Symbols have usual meaning unless otherwise stated.

(5) Use of **non-programmable** calculator is allowed.

List of Constants:

Charge of an electron: $e = 1.6021 \times 10^{-19}$ Coulomb

Mass of an electron: $m = 9.109 \times 10^{-31}$ Kg

Boltzmann constant: $K = 1.3805 \times 10^{-23}$ Joule/ Kelvin

Plank's constant: $h = 6.626 \times 10^{-34}$ Joule-sec

Permeability of free space: $\mu_0 = 4\pi \times 10^{-7}$ Henry/meter

Avogadro's number: $N_A = 6.023 \times 10^{26}$ /Kmole

1. (a) Attempt any **one:---**

(i) Derive the expression for interplaner distance between two consecutive planes in simple cubic crystal system. **10**

(ii) On the basis of classical electron theory explain the terms relaxation time and mean free path. Derive expressions for relaxation time in terms of drift velocity. **10**

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

(i) Derive the expression for the atomic packing factor of body centered cubic crystal with help of neat diagram. **5**

(ii) Calculate the lattice constant for $\alpha -$ iron with bcc structure. **5**
[Given: Density of $\alpha -$ iron$= 7.86 \times 10^3 kg/m^3$ and $atomic\ weight = 55.85$]

2. (a) Attempt any **one:---**

(i) Explain the Brillouin zones in one dimension and two dimensions with neat diagram. How are they related to the energy levels of an electron in a solid? **10**

(ii) Discuss $Krönig - Penney$ model for the motion of an electron in periodic potential. Thus explain the band theory for solids. **10**

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

(i) Show how $F(E)$ varies with energy for a metal at $T = 0\ K, 300\ K\ and\ T \rightarrow \infty$. **5**

(ii) Obtain the expression between mean energy of electron gas in terms of Fermi energy at absolute zero. **5**

3. (a) Attempt any **one:---**

(i) Derive the expression of concentration of electrons in conduction band for an intrinsic semiconductor. Hence state the expression for hole concentration in its valance band. **10**

(ii) Explain the concept of carrier lifetime. Set up the continuity equation for the charge carriers in a semiconductor. **10**

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

(i) What is p-n junction diode? Draw the energy level diagram of p-n junction and explain why a contact potential difference is developed across an unbiased p-n junction. **5**

(ii) The energy gap of silicon is 1.1 eV. Its electron and hole mobilities at room temperature are 0.48 and 0.013 $m^2V^{-1}s^{-1}$ respectively. Calculate its conductivity. For Si, $n_i = 2.15 \times 10^{19}$ /m^3. **5**

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

(i) Derive the expression for volt-ampere characteristic of p-n junction diode. **10**

(ii) What is the Meissner effect? Explain the effect of magnetic field on superconductivity. What do you mean by the penetration depth in relation to superconductivity? **10**

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

(i) What is paramagnetism? Explain the origin of permanent magnetic dipole due to orbital motion of an electron. **5**

(ii) Calculate the static and dynamic resistance of a germanium p-n junction diode, at room temperature of 27 °C if its reverse saturation current is 2 μ A and a forward bias of 0.2 volts is applied to it. **5**

5. (a) Attempt any **one:---**

(i) Draw $(1\ 1\ 1), (0\ 0\ 1), (1\ 2\ 3) and\ (2\ 0\ 0)$ planes for simple cubic crystal system. **4**

(ii) The resistivity of aluminium at room temperature is $2.62 \times 10^{-8}\ ohm.m$. Calculate relaxation time on the basis classical free electron theory. Density of Al=2700Kg/m^3. **4**

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

(i) Using the Fermi-Dirac distribution function obtain the value of $F(E)$ for $E - E_f = 0.01\ eV$ at $200\ K$. **4**

(ii) Calculate the total number of states below $E = 5\ eV$ in a metal of volume $10^{-5}\ m^3$. Assume the electrons to be free. **4**

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

(i) Compare the densities of charge carriers in a pure germanium crystal at the temperatures 300 K and 320 K. The energy gap for germanium is 0.7 eV. **4**

(ii) For Ge p-n diode, $N_D = 10^4 N_A$ and N_A is corresponding to 1 acceptor atom per 10^8 Ge atoms. Calculate the barrier height E_0 in eV at room temperature. For Ge, $n_i = 2.15 \times 10^{19}$ /m^3 and atomic density is 4.42×10^{28} atoms/m^3. **4**

(d) Attempt any **one:**---

(i) Calculate the value of applied forward voltage for a p-n junction diode if $I_s = 50\mu A$, forward current I= 2A and e/KT=40 per volt. **3**

(ii) A paramagnetic substance has 10^{28} atoms/ m^3. The magnetic moment of each atom is 1.8×10^{-23} A-m^2. Calculate the paramagnetic susceptibility at 300 K. **3**
