

(2 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:

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|--------------------------------|--|
| 1. Charge on electron | $e = 1.6 \times 10^{-19} \text{ C}$ |
| 2. Electron mass | $m = 9.1 \times 10^{-31} \text{ Kg}$ |
| 3. Planck's constant | $h = 6.62 \times 10^{-34} \text{ js}$ |
| 4. Velocity of light in vacuum | $c = 3 \times 10^8 \text{ m/s}$ |
| 5. Permeability of free space | $\mu_0 = 1.257 \times 10^{-6} \text{ N}\cdot\text{A}^{-2}$ |
| 6. Permittivity of free space | $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 / \text{N}\cdot\text{m}^2$ |
| 7. Avogadro 's number | $N_A = 6.02 \times 10^{26} \text{ Kg- mol}^{-1}$ |
| 8. Boltzmann constant | $k = 1.38 \times 10^{-23} \text{ J/K}$
$= 8.625 \times 10^{-5} \text{ e V/K}$ |
| 9. Bohr magneton | $\mu_B = 9.27 \times 10^{-24} \text{ ampere- meter}^2$ |

1. (a) Attempt any **one**:---
- (i) Explain thermionic emission in metals. Derive an expression for the emitted current density. 10
- (ii) Derive the expression of Fermi energy and average energy of electron gas at absolute zero. Assume the expression of density of states. 10
- (b) Attempt any **one**:---
- (i) Explain drift velocity, relaxation time and mean free path as applied to free electron in a metal. 5
- (ii) Find the temperature at which there is 1% probability that a state with energy 0.5 eV above fermi energy will be occupied. 5
2. (a) Attempt any **one**:---
- (i) Discuss the Kronig- Penney model for behavior of an electron in a one dimensional periodic lattice. Show that it leads to the occurrence of allowed and forbidden bands for the electrons. 10
- (ii) Explain Meissner effect in superconductors. Hence discuss Type I and Type II superconductors 10

- (b) Attempt any **one**:---
- (i) Explain how materials can be classified into conductors, insulators and semiconductors on the basis of E-K curve for the materials. 5
 - (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 and 1K. 5
3. (a) Attempt any **one**:---
- (i) Explain Langevin's classical theory of Paramagnetism. Derive an expression for the paramagnetic susceptibility of metal at ordinary temperature and normal field strength 10
 - (ii) Discuss Weiss field theory of Ferromagnetism. Hence derive a relation between ferromagnetic Curie temperature and Weiss constant 10
- (b) Attempt any **one**:---
- (i) Explain the origin of permanent magnetic dipole moments in a solid and obtain the relation between magnetic dipole moment and angular momentum of an orbiting electron. 5
 - (ii) A magnetic field strength of a material is 10^5 A/m. If the magnetic susceptibility of the material is $-(0.8 \times 10^{-5})$, calculate magnetization and magnetic flux density. 5
4. (a) Attempt any **one**:---
- (i) What is p - n junction? With the help of energy band diagram of an unbiased p-n junction explain the terms: Depletion region and Potential barrier. 10
 - (ii) Derive an expression for electron concentration in an intrinsic semiconductor, hence write the expression for hole concentration at absolute temperature (T). 10
- (b) Attempt any **one**:---
- (i) Draw the volt-ampere characteristics of the p-n junction diode. Explain how they depend on the temperature. 5
 - (ii) A germanium p-n junction diode has reverse saturation current of $2 \mu\text{A}$ at 27°C . Find its static and dynamic resistance for an applied forward bias of 0.3 V at 27°C . 5

5. (a) Attempt any **one**:---
- (i) The density of silver is 10^4 Kg / m^3 , the atomic weight of silver is 107.9 a.m.u. The conductivity of silver at 20°C is $7 \times 10^7 \Omega^{-1} \text{ m}^{-1}$. Calculate the collision time in silver. 4
- (ii) Find the Fermi velocity and temperature of electron in sodium at 0 K for $E_{F0} = 3.2 \text{ eV}$. 4
- (b) Attempt any **one**:---
- (i) Calculate critical current through Tungsten wire of diameter 2.8 mm and $H_c = 8.51 \times 10^7 \text{ A/m}$. 4
- (ii) A two dimensional square lattice has side of 0.85 nm. Calculate momentum and energy of the free electron of first Brillion zone. 4
- (c) Attempt any **one**:---
- (i) Consider helium atom in its ground state. The mean radius is 0.528nm. Density of helium is 0.178 kg/m^3 . Calculate the diamagnetic susceptibility of the helium atom. Atomic mass of helium = $4.003u$ 4
- (ii) A magnetic material made of steel has a magnetic moment of 3 Am^2 and a mass of $6 \times 10^{-3} \text{ kg}$. If the density of steel is $7.9 \times 10^3 \text{ kg m}^{-3}$, find magnetic flux density when it is placed in magnetic field of 1000 Amp/m . 4
- (d) Attempt any **one**:---
- (i) For an intrinsic semiconductor with gap width $E_g = 0.7 \text{ eV}$, calculate the concentration of intrinsic carrier at 300 K. Given $m_0 = 9.1 \times 10^{-31} \text{ kg}$, $N_c = 5 \times 10^{25} \text{ m}^{-3}$. 3
- (ii) An electric field of 50 V/m is applied to a sample of n-type semiconductor whose Hall coefficient is $-(0.015 \text{ m}^3/\text{C})$. Determine the carrier charge density (n) in the sample. 3
