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

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

(2) Figures to the right indicate full marks

(3) Neat diagrams should be drawn wherever necessary.

(4) Use of calculators /log tables is allowed.

(5) Symbols have their usual meaning unless otherwise stated.

List of Constants:

Charge of an electron e = 1.6021×10^{-19} Coulomb

Mass of an electron m_e = 9.109×10^{-31} kg

Boltzmann constant k = 1.38054×10^{-23} Joule/Kelvin

Planck's constant h = 6.626×10^{-34} joule sec

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

Q.1 A Attempt any ONE: 10

i) Give the outline of classical theory of metallic conduction and hence deduce Ohm's law.

ii) Derive an expression for density of energy states in metals at an energy E.

B Attempt any ONE: 05

i) Based on Fermi-Dirac statistics, state the nature of the Fermi distribution function. State and explain how it will vary with temperature.

ii) Compute the average kinetic energy of a gas molecule at 27^0C. Express the result in eV. If the gas is hydrogen, what is the order of magnitude of the velocity of the molecules at 27^0C.

Given: Mass of hydrogen atom = $1.008 \times 1.67 \times 10^{-27} Kg$

Q.2 A Attempt any ONE: 10

i) Using E-k curve derive an expression for the effective mass of electron. Explain with relevant graphs the variation in effective mass of electron with wave vector k.

ii) State the salient features of superconductivity. Explain how the superconducting transition temperature varies with magnetic field.

{TURNOVER

B Attempt any ONE: 05

i) Discuss the conclusions of Kronig – Penny model with the scattering power of potential as : a) $P \to 0$ and b) $P \to \infty$

ii) Calculate the critical current density which can flow through a long thin superconducting wire of aluminium of diameter 10^{-3} m. The critical magnetic field for Aluminium is 7.9×10^3 Amp/m

Q.3 A Attempt any ONE: 10

i) What is diamagnetism? Derive an expression for the Larmor Frequency of precession of angular momentum vector about the direction of applied field and hence obtain an expression for the diamagnetic susceptibility for a spherical charge distribution in an atom.

ii) Discuss the quantum theory of Paramagnetism. Derive an expression for paramagnetic susceptibility at ordinary field and normal temperature.

B Attempt any ONE: 05

i) Write a note on Antiferromagnetism.

ii) The magnetic field strength in silicon is 1000 A/m. If the magnetic field susceptibility is -0.3 x10^{-5}, calculate the magnetization and flux density in silicon.

Q.4 A Attempt any ONE: 10

i) Obtain an expression for concentration of electrons in an intrinsic semiconductor. Assuming the expression for concentration of holes for an intrinsic semiconductor, prove that its Fermi energy lies exactly halfway between the top of the valence band and bottom of the conduction band for $m^*_h = m^*_e$

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

B Attempt any ONE: 05

i) Discuss the temperature dependence of saturation current for Ge and Si p-n junction diodes.

{TURNOVER

ii) An electric field of 100V/m is applied to the sample of n-type semiconductor whose hall coefficient is found to be $-0.0125 m^3/C$. Determine the current density in the sample assuming the mobility of the electron is $0.36 m^2/Vs$

Q.5 A Attempt any ONE: 04

i) The Fermi temperature of copper is $8.18 \times 10^4 K$. Calculate the Fermi velocity of electrons in copper.

ii) The Fermi energy of silver is 5.51 eV. Calculate a) The average energy of the free electrons of silver at 0 K. b) Speed of the electrons with this energy.

B Attempt any ONE : 04

i) The magnetic field intensity in the tin material is zero at a temperature of 3.69 K and $2.387 \times 10^4 A/m$ at zero kelvin. Calculate the temperature of the superconductor state if the field intensity measured was $1.591 \times 10^4 A/m$

ii) Consider a two dimensional square lattice of sides 0.25 nm. At what electron momentum values do the sides of the first Brillouin zone comes? Calculate the energy of the free electron with this momentum.

C Attempt any ONE : 04

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

ii) A magnetic material made of steel has a magnetic moment of 2.5 Am^2 and a mass of 6.6×10^{-3} kg. If the density of steel is 7.9×10^3 kg/m^3, find the magnetization of the material.

D Attempt any ONE: 03

i) In an n-type semiconductor, the Fermi level lies 0.4 eV below the conduction band. If the concentration of donor atoms is doubled, find the new position of the Fermi level. Assume KT= 0.003 eV.

ii) In an intrinsic semiconductor, the effective mass of the electron is $0.07 m_o$ and that of the hole is $0.4 m_o$ where m_o is the rest mass of the electron. Calculate the intrinsic concentration of charge carriers at 300K. Given: E_g= 0.68 eV

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