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3 (Sem-5 /CBCS) PHY HC 2

2023

PHYSICS

(Honours Core)

Paper : PHY-HC-5026

(Solid State Physics)

Full Marks : 60

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Choose the correct answer from the following : $1 \times 7 = 7$

(a) If N is the number of primitive cells in a specimen, the number of orbitals in the band will be

(i) N

(ii) $2N$

(iii) $3N$

(iv) $4N$

Contd.

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(b) A superconductor exhibits

- (i) infinite conductivity
- (ii) finite conductivity
- (iii) zero conductivity
- (iv) negative conductivity

(c) First Brillouin zone of a body-centred cubic lattice is

- (i) cube
- (ii) sphere
- (iii) rhombic dodecahedron
- (iv) truncated octahedron

(d) Packing fraction of simple cubic cell is

- (i) 0.52
- (ii) 0.68
- (iii) 0.74
- (iv) 1

(e) The material that does not have permanent magnetic dipoles is

- (i) anti-ferromagnetic
- (ii) ferromagnetic
- (iii) diamagnetic
- (iv) paramagnetic

(f) Four probe method is used for the experimental measurement of

- (i) conductivity of semiconductor
- (ii) charge carrier density
- (iii) energy band gap of semiconductor
- (iv) band gap and conductivity of semiconductor

(g) The electron pairs in a superconductor are called

- (i) Cooper pair
- (ii) BCS pair
- (iii) positron pair
- (iv) electron-hole pair

2. Answer the following questions : $2 \times 4 = 8$

- (a) What is reciprocal lattice vector ?
- (b) What is the energy eigenvalue for a phonon of frequency ω ? What is its zero point energy ?
- (c) Draw a simple energy band diagram of n -type semiconductor showing conduction band, valence band, donor level and Fermi level.
- (d) Explain how Meissner effect may be used to distinguish between type I and type II superconductors.

3. Answer **any three** of the following questions : $5 \times 3 = 15$

- (a) Show that reciprocal of the reciprocal lattice is the direct lattice.
- (b) Deduce the vibrational modes of a diatomic lattice stating the acoustic and optical modes.
- (c) Elaborate the basic features of Debye model of lattice heat capacity.
- (d) What is ferromagnetic domain ? Discuss in brief the domain theory of ferromagnetism.

(e) Obtain an expression for conductivity of an intrinsic semiconductor.

4. Answer **any three** of the following questions : $10 \times 3 = 30$

- (a) (i) Write down the Bragg's law of X-ray diffraction. Calculate the glancing angle for (100) plane of cubic structured crystal with $a = 2.814 \text{ \AA}$ corresponding to second order X-ray diffraction maximum of wavelength 0.710 \AA .
 $1 + 3 = 4$

(ii) What are the various symmetry elements associated with a crystal ? 2

(iii) What do you mean by atomic scattering factor and geometrical structure factor ? $2 + 2 = 4$

(b) (i) Obtain the classical Langevin equation for diamagnetism to show that diamagnetic susceptibility is independent of temperature and field strength. 6

(ii) Write down the Curie law for a paramagnetic substance. What is Curie temperature ? 2

(iii) What do you mean by hysteresis of a ferromagnetic material? Why hysteresis loop of a ferromagnetic material is important in practical application of the material? 2

(c) (i) Use the basic idea of Kronig-Penney model to show that the motion of electrons in the periodic potential of solids give rise to the formation of allowed and forbidden energy bands. 7

(ii) The intrinsic resistivity of silicon at 27°C is $2.8 \times 10^3 \Omega\text{m}$. The electron and hole mobilities are $0.38 \text{ m}^2\text{V}^{-1}\text{s}^{-1}$ and $0.18 \text{ m}^2\text{V}^{-1}\text{s}^{-1}$ respectively. Calculate the intrinsic carrier density at the given temperature. 3

(d) (i) Explain the phenomenon of super-conductivity using the elementary idea of BCS theory. 3

(ii) Define Critical temperature, Critical magnetic field and Isotope effect related to superconductivity. 3

(iii) Show that in case of a super-conductor magnetic field decreases rapidly with distance from the surface. 4

(e) (i) Differentiate between ferroelectricity and piezoelectricity. 2

(ii) Consider an electron of charge ' $-e$ ' rotating in a circular orbit of radius r in a field directed at right angles to the plane of the orbit. Show that polarizability

$$\alpha = 4\pi\epsilon_0 r^3 \quad 4$$

(iii) What do you mean by normal and anomalous dispersion? 2+2=4

(f) (i) What is the difference between classical free electron theory and quantum free electron theory in solid state physics? 2

(ii) Copper has electrical conductivity at 300K as $6.4 \times 10^7 \text{ mho/m}$. Calculate the thermal conductivity of copper. Lorentz number $L = 2.45 \times 10^{-8} \text{ W}\Omega\text{K}^{-2}$. 2

(iii) What is Hall effect? Derive an expression for Hall co-efficient of a semiconductor. 1+3=4

(iv) A silicon plate of thickness 2 mm, breadth 8 mm and length 80 cm is placed in a magnetic field of 0.5 Wb/m^2 acting perpendicular to its thickness. If 10^{-2} A current flows along its length, calculate the Hall voltage developed if the Hall co-efficient is $3.66 \times 10^{-4} \text{ m}^3/\text{coulomb}$. 2