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) $4N$

(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 latice 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 super-conductor are called

(i) Cooper pair

(ii) BCS pair

(iii) positron pair

(iv) electron-hole pair

2. Answer the following questions : 2×4=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 : 5×3=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 : 10×3=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 $a = 2.814$Å corresponding to second order X-ray diffraction maximum of wavelength 0.710Å. 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 Langevien 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 2.8×10^3 Ωm. The electron and hole mobilities are 0.38 $m^2v^{-1}s^{-1}$ and 0.18 $m^2v^{-1}s^{-1}$ 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

$$\alpha = 4\pi \varepsilon_0 r^3$$ 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 6.4×10^7 mho/m. Calculate the thermal conductivity of copper. Lorentz number $L = 2.45\times10^{-8} W\Omega K^{-2}$. 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 3.66×10^{-4} $m^3/coulomb$. 2