2023

PHYSICS — HONOURS

Paper : CC-14

(Syllabus : 2019-2020)

[Solid State Physics]

Full Marks : 50

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Answer ***question no.*** **1** and ***any four*** questions from the rest.

1. Answer ***any five*** questions : 2×5

(a) Distinguish between crystalline and amorphous solids with suitable example.

(b) In an orthorhombic crystal a lattice plane cuts intercepts of lengths 3a, –2b and 3c/2 along the three axes. Deduce the Miller indices of the plane.

(c) Consider two ferromagnets : one having a hysteresis curve with broad area and another with a narrow area. Which one can be used as permanent magnet and why?

(d) In a tetrahedral lattice the equal sides are 2.5 Å and the third side is 1.8 Å. Find the lattice spacing between (111) planes.

(e) Taking the origin at the bottom of the conduction band, calculate the crystal momentum for a free electron of energy 0.02 eV. Given, effective mass of electron = $0.2\ m_0$.

(f) For a superconductor, what do you mean by critical temperature and critical field?

(g) What is dipolar polarisation? How does it depend on temperature?

2. (a) Write down the Laue condition for constructive interference in a crystal and derive the Bragg's law for X-ray diffraction for a simple cubic lattice.

(b) Monochromatic X-rays of wavelength 1.4 Å are incident on a crystal having 1.5 Å as interatomic spacing. Find the maximum order in which the diffraction takes place.

(c) Show that greater the diffraction angle, greater is the accuracy in determining the lattice parameters. (2+3)+3+2

3. (a) Show schematically the acoustic and optical branches due to a linear diatomic lattice in the first Brillouin zone.

(b) Write down the expressions for phase velocity and group velocity of wave motion along a 1-dim lattice. What happens to the group velocity when $Ka = \pm \pi$?

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(c) Indicate the problem encountered in Einstein's model to explain the behaviour of specific heat of lattice at low temperature. What approximation led Debye to match the observed behaviour at low temperature?

(d) The molar specific heat of a solid at constant volume is 2.77 JK^{-1} mol^{-1} at 36.8 K. Determine the Debye temperature of the solid. 2+(2+1)+(1+2)+2

4. (a) What is the basic assumption of the quantum theory of paramagnetism? For strong magnetic field and at low temperature find out the expression for magnetisation.

(b) The outer electronic configuration of Dy^{3+} ion is $4f^9 6s^0$. Calculate the magnetic susceptibility for a salt containing 1 kg mole of Dy^{3+} at 300 K.

$$\left(\text{Given}: \mu_0 = 4\pi\times10^{-7}\ NA^{-2},\ N = 6.023\times10^{26},\ \mu_B = 9.27\times10^{-24}\ JT^{-1},\ k = 1.38\times10^{-23} JK^{-1}\right)$$

(2+4)+4

5. (a) The relative permittivity and square of retractive index of a dielectric material are 4.94 and 2.69 respectively. Find the ratio between electronic and ionic polarizabilities of the material.

(b) From the free electron theory find out the temperature dependence of resistivity.

(c) Calculate the Fermi energy at absolute zero of Na-metal (BCC) if its atomic radius is 1.86Å.

$$\left[\hbar = 1.05\times10^{-34}\ Js,\ m = 9.1\times10^{-31} kg\right]$$

4+3+3

6. (a) State and explain Bloch theorem.

(b) Show that the effective mass is inversely proportional to the second derivative of the E-K curve.

(c) Discuss, with the help of diagrams, the condition when the effective mass becomes positive, negative and infinity.

(d) The dispersion relation for a 1-d crystal is given by $E(K) = E_o - \alpha - 2\beta \cos Ka$, where E_o, α, β are constants. Obtain the effective mass at the bottom and top of the band. (2+1)+2+(1+2)+2

7. (a) Derive Hall-coefficient of charge carrier in a metal. Will the Hall-coefficient change sign if one reverses the direction of the applied magnetic field? Explain briefly.

(b) What is isotope effect in superconductivity? Name two experiments from which we can get an idea of existence of energy gap in superconductor.

(c) For lead, the critical field at 0K is 6.39×10^4 A/m and the critical temperature for zero magnetic field is 7.18 K. Find the critical field for lead at 4K. (3+2)+(1+2)+2