2020

PHYSICS — HONOURS

Paper : CC-12

(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 rest.

1. Answer ***any five*** questions : 2×5=10

(a) Determine the Miller indices of a set of parallel planes which make intercept in the ratio $3a : 4b$ on X and Y axes and are parallel to Z-axis, where a, b and c are the primitive vectors of the lattice.

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

(c) Will the Hall-Effect change sign if one reverses the direction of applied magnetic field? Justify your answer.

(d) Explain hysterisis on the basis of domain theory.

(e) The relative permittivity (ϵ_r) of Argon at NTP is 1·000435. Calculate the electronic polarizability of Argon atom.

(f) Sketch the temperature variation of specific heat of a superconductor and a normal metal in the same graph.

(g) What is the physical significance of Fermi-level in semiconductor?

2. (a) Write down Laue's condition for constructive interference in a crystal. Derive Bragg's law from it for a simple cubic lattice. Also obtain the vector form of Bragg's law using the concept of reciprocal lattice.

(b) Show that the reciprocal lattice corresponding to an FCC lattice is a BCC lattice.

(c) Show that the packing fraction of a BCC lattice is 0·68. (1+2+2)+3+2

3. (a) The phonon dispersion relation for a vibrating diatomic chain in which alternate atoms are of mass M_1 and M_2 is given by

$$\omega^2 = K_1\left(\frac{1}{M_1}+\frac{1}{M_2}\right) \pm K_1\left[\left(\frac{1}{M_1}+\frac{1}{M_2}\right)^2 - \frac{4\sin^2 Ka}{M_1M_2}\right]^{\frac{1}{2}}$$

where K_1 = force constant, $K = \frac{2\pi}{\lambda}$.

Obtain the minimum and maximum angular frequency of the acoustical and optical branch.

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(b) Obtain the expressions of specific heat of solid according to Einstein's theory at high temperature and low temperature limits.

(c) Debye temperature of a solid is 1500 K. Compute the highest vibrational frequency of the solid at 30K. (2+2)+4+2

4. (a) What is Weiss molecular field? Starting from the basic assumptions of Weiss molecular field theory and assuming the relation $M = NgJ\,\mu_B B_j(x)$ [where the symbols have their usual meaning], derive the Curie-Weiss law of ferromagnetism.

(b) The Curie temperature of Iron is 1043 K and each iron atom has a magnetic moment of two Bohr magneton. Iron is a BCC lattice with lattice parameter 0·286 nm. Given $\mu_B = 9{\cdot}2741\times10^{-24}$ J/T. Determine (i) the saturation magnetisation (ii) the Curie constant and (iii) the Weiss constant. (2+4)+(2+1+1)

5. (a) What are the basic assumptions of Kronig Penny Model?

(b) Kronig Penny Model gives a simplified form of energy levels in periodic lattice as

$$P\frac{\sin\alpha a}{\alpha a}+\cos\alpha a=\cos Ka$$

where $P=\frac{mV_0ab}{\hbar^2}$, $\alpha^2=\frac{2mE}{\hbar^2}$ and symbols have their usual meaning.

(i) What is the dimension of P ? What is its physical significance?

(ii) Plot the graphical variation of LHS (with $P=3\pi/2$) as a function of 'αa' and hence explain the appearance of allowed energy bands separated by forbidden regions.

(iii) Discuss energy spectrum of electron in the two extreme cases i.e., when $P\to\infty$ and $P\to 0$.

(c) Distinguish metals, insulators and semiconductors on the basis of band theory of solid. 2+(2+2+2)+2

6. (a) What is meant by complex dielectric constant?

(b) Clearly explaining the basic assumptions, derive Clausius-Mosotti relation for a dielectric. Explain how it is modified when more the one dielectric is present.

(c) Determine the percentage of ionic polarizability of NaCl crystal having refractive index of 1·5 and static dielectric constant of 5·6. 2+(4+2)+2

7. (a) What is Meissner Effect? The perfect diamagnetism and Zero resistivity of a superconductor are the two mutually exclusive properties.— Explain. Discuss the difference between type-I and type-II superconductors.

(b) Estimate the London penetration depth for 'tin' (density 7300 kg m^{-3}). Given the atomic weight = 118.7 u, T_C = 3·7 K and effective mass of electron $m^* = 1{\cdot}9\ m_e$.

(c) Briefly explain how BCS theory accounts for the superconducting state. (1+2+2)+3+2

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