

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
- 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.
 - Distinguish between crystalline and amorphous solids with suitable example.
 - Will the Hall-Effect change sign if one reverses the direction of applied magnetic field? Justify your answer.
 - Explain hysteresis on the basis of domain theory.
 - The relative permittivity (ϵ_r) of Argon at NTP is 1.000435 . Calculate the electronic polarizability of Argon atom.
 - Sketch the temperature variation of specific heat of a superconductor and a normal metal in the same graph.
 - 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

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

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

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

Please Turn Over

- (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 $\mu_B = 9.2741 \times 10^{-24}$ 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 $P \rightarrow \infty$ and $P \rightarrow 0$.
- (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, $T_C = 3.7 \text{ K}$ and effective mass of electron $m^* = 1.9 m_e$.
- (c) Briefly explain how BCS theory accounts for the superconducting state. (1+2+2)+3+2