B.Sc. 5th Semester (Honours) Examination, 2024 (CBCS)

Subject : Physics

Course : CC-XII

(Solid State Physics)

Time: 2 Hours **Full Marks: 40**

The figures in the margin indicate full marks.

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

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

(a) Prove that every reciprocal lattice vector is perpendicular to a set of direct lattice planes.

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

(c) In a crystalline solid, the energy band structure for an electron of mass 'm' is given by $E = \frac{\hbar^2 k(2k-3)}{2m}$, find the effective mass of the electron in the crystal.

(d) State Bloch theorem. What is the outcome of the theory?

(e) Discuss the phenomenon of anti-ferromagnetism.

(f) What do you understand by 'lattice heat capacity'?

(g) Explain the differences between Type I & Type II superconductors.

(h) The transition temperature of mercury with an average atomic mass of 200·59 u is 4·153K. Determine the transition temperature of one of its isotopes $_{80}Hg^{204}$.

2. Answer *any two* questions: 5×2=10

(a) (i) The molecular weight of rock salt (SC) crystal is 5·85 kg/kmole and its density is $2{\cdot}16 \times 10^3$ kg/m^3. Calculate the grating space d_{100} of rock salt and the wavelength of X-rays in the second order, if the angle of diffraction, $\theta = 26°$.

(ii) Copper has FCC structure and the atomic radius is 0·1278 nm. Calculate the interplanar spacing for (212) plane. 3+2

(b) (i) What are ferroelectric crystals? Give examples.

(ii) Show that the Polarizability of ferroelectric crystals varies with temperature. (1+1)+3

(c) What do you mean by 'London Penetration depth'? Find an expression for it using London equation. 1+4

(d) Give the Debye's theory of specific heat of a 3-dimensional crystalline solid and show that in suitable limits it gives Dulong and Petit's law and the T^3 law. 5

3. Answer *any two* questions: 10×2=20

(a) (i) Consider a paramagnetic solid of N atoms. Each atom is characterized by total angular quantum number J. Considering quantized energy levels in presence of a magnetic field H, find a general expression of magnetization (μ) at temperature T. Find the same for the extreme case $J = ½$ and $J = \infty$.

(ii) A system of electron spins, placed in a magnetic field of 5 Tesla at temperature T, shows that the number of spins parallel to the magnetic field is twice the number of anti-parallel spins. Calculate the value of the temperature. 4+(1½+1½)+3

(b) (i) The field seen by dipoles in a solid differ from the applied field.— Why?

(ii) Derive Clausius-Mossotti relationship and name the solids for which it holds.

(iii) The crystal of Nacl has static dielectric constant of 5·6 and optical index of refraction 1·5. Calculate the percentage contribution of ionic polarizability. 2+(3+1)+4

(c) (i) The energy near a valence band edge is given by $E(\mathrm{K}) = -1 \times 10^{26}\mathrm{K}^2$ ergs. An electron is removed from the orbital $\mathrm{K} = 1 \times 10^{7}\mathrm{K_x}\ \mathrm{cm}^{-1}$, the band is otherwise full. Give the sign and magnitude of the effective mass of the hole.

(ii) Derive an expression for density of electrons in the conduction band for an n-type semiconductor.

(iii) Starting with the solution of Schrödinger equation for one dimensional periodic lattice $P\frac{\sin \alpha a}{\alpha a} + \cos \alpha a = \cos \mathrm{K}a$, with $\alpha = \sqrt{\frac{2mE}{\hbar^2}}$, discuss the formation of energy bands in solids. 2+4+4

(d) (i) Explain the fact that (100), (300) reflection lines vanish for metallic sodium but not for Cs having BCC structure.

(ii) Given that the diamagnetic susceptibility of He is $-1{\cdot}9 \times 10^{-6}$ per mole, estimate the radius of the He atom.

(iii) The Debye temperature for diamond is 2230K. Find the highest possible vibrational frequency and the molar heat capacity of diamond at 10K. 3+3+4
