B.Sc. 5th Semester (Honours) Examination, 2023 (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.

Group-A

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

(a) In X-ray diffraction pattern, using X-rays of wavelength 1.54Å, three consecutive peaks of 1st order are observed at 2θ values of 60°, 90° and 112°. If the system is cubic and peak at 90° corresponds to (220) plane, calculate the lattice constant.

(b) What is the phase velocity and group velocity of the wave motion along a one-dimensional lattice? What happens to the group velocity when $a = \pm\pi$?

(c) What do you mean by 'effective mass' of an electron in a solid? Under what condition the effective mass of electron is equal to its free electron mass?

(d) Explain 'isotope effect' in superconductivity. Briefly discuss its significance.

(e) Define Néel Temperature. What are ferrites?

(f) The distance between (110) planes in a BCC crystal is 2Å. Determine the atomic radius.

(g) The relative permittivity and square of refractive index of a dielectric material are 4.94 and 2.69 respectively. Find the ratio between electronic and ionic polarizability of the material.

(h) Resistivity of a intrinsic semiconductor is 4.5 Ωm at 20°C and 2 Ωm at 32°C. Find the band gap of the semiconductor.

Group-B

2. Answer *any two* questions: 5×2=10

(a) (i) Calculate the Hall coefficient in a solid where both electrons and holes contribute to the Hall effect.

(ii) Show that at absolute zero, Fermi level lies exactly half way between the top of the valence band and the bottom of the conduction band. 3+2

(b) The wavefunction of the hydrogen atom in the ground state is given by $\psi(r) = \frac{1}{(\pi a_0^3)^{\frac{1}{2}}} e^{-\frac{r}{a_0}}$. Show that $< r^2 > = 3a^2$ and calculate the molar diamagnetic susceptibility of atomic hydrogen at STP, where a_0 = atomic radius = 0.46Å. 5

(c) (i) The Bragg angle for first order reflection from (111) plane of a SC crystal is 60°. Calculate the interatomic spacing, if X-rays of wavelength 1·8Å is used.

(ii) Define geometrical structure factor. Derive an expression for the scattering amplitude in terms of geometrical structure factor. 2+3

(d) (i) Show that in the Debye approximation the total zero point energy/gm-mole of solid is given by $\frac{9}{8} R\, \theta_D$.

(ii) Calculate atomic packing fraction of a crystal having FCC structure. 3+2

Group-C

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

(a) (i) Discuss the Weiss field theory of ferromagnetism and explain how magnetic susceptibility varies with temperature at Curie point and above Curie point.

(ii) The atomic radius of sodium is 1·86Å. Calculate the Fermi energy of sodium (BCC) at absolute zero. 7+3

(b) (i) Derive the Meissner effect from the Second London equation, using the Maxwell's relation $\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}_s$.

(ii) What is Cooper-pair? Find the wavelength of the photon that would break a Cooper-pair in a superconductor whose critical temperature is 1.2K. 5+(3+2)

(c) (i) Derive the Langevin-Debye equation. How could this equation be used to obtain information regarding the molecular structure? Which materials exhibit orientational polarizability?

(ii) The dielectric constant of a helium gas at NTP is 1.0000684. Calculate the electron polarizability of helium atoms if the gas contains $2{\cdot}7 \times 10^{26}$ atoms/m^3 and hence calculate the radius of helium atom. 6+(2+2)

(d) (i) Derive vibrational modes of a diatomic linear lattice.

(ii) Name the different branches of the dispersion relation curve. What is the difference between the two branches? 6+(1+3)
