

2022

5th Semester Examination

PHYSICS (Honours)

Paper : C 12-T

[Solid State Physics]

[CBCS]

Full Marks : 40

Time : Two Hours

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* of the following questions : $2 \times 5 = 10$

- (a) In a crystalline solid, the energy band structure (E - k relation) for an electron of mass m is given

by $E = \frac{h^2 k(2k-3)}{8\pi^2 m}$. Find the effective mass of the electron in the crystal.

- (b) The critical temperature for mercury with isotope mass 202 at 4.159K. Determine its critical temperature when its isotope mass is 200.7.

- (c) A plane makes intercepts of 1, 2, 3 Å on the crystallographic axes of an orthorhombic crystal with $a : b : c = 3 : 2 : 1$. Determine the Miller indices of this plane.

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- (d) Comment on how the resistivity of a metal varies with temperature (T) when $T \ll \theta_D$ and $T \gg \theta_D$.
- (e) What is piezoelectricity? Give an example of a crystal that is piezoelectric but not ferroelectric.
- (f) Determine the percentage of ionic polarizability for water which has the optical index of refraction and the static dielectric constant as 1.33 and 8.1 respectively.
- (g) Plot the dispersion relation for one-dimensional diatomic lattice containing heavier atom with infinite mass. Write down the physical significance of this diagram.
- (h) The high temperature magnetic susceptibility of solids having ions with magnetic moments can be described by $\chi = \frac{C}{T - \theta}$, T as absolute temperature and θ as a constant. How do the values of θ assume in the cases of paramagnetic and ferromagnetic substances?

Group - B

Answer any **four** from the following questions :

$$5 \times 4 = 20$$

2. (i) Copper (fcc) has a lattice parameter of $3.61 \text{ \AA}$. The first order Bragg reflection from (111) planes appear at an angle of 21.7° . Determine the wavelength of x-rays used.

- (ii) Calculate the geometrical structure factor for the *fcc* structure. Explain the fact that (111) reflection line vanishes for *KCl* but not for *NaCl*, both having the *fcc* structure. 2+(2+1)
3. (a) Why does the concept of local field originate for a dielectric? Derive the expression of the local field. 1+3
- (b) What is the significance of complex dielectric constant in case of a dielectric? 1
4. (a) State arguments behind the emergence of 'critical magnetic field'. 1
- (b) The critical field and critical temperature of Lead are 6.5×10^4 A/m and 7.18K, respectively. To what temperature it must be cooled to become a superconductor in a magnetic field of 2×10^4 A/m. 2
- (c) Give a short account of Cooper Pair. 2
5. (a) Deduce the Hall coefficient for a semiconductor sample of width (b) and thickness (t) when the current through the sample is I and the applied magnetic induction is B. 3
- (b) Consider a doped semiconductor having the electron and the hole mobilities μ_n and μ_p , respectively. Its intrinsic carrier density is n_i . Derive the expression of the hole concentration (p) for which the conductivity is minimum at a given temperature. 2

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6. (a) Show that the total number of possible wave functions in any energy band is equal to the number of primitive unit cells.
- (b) Determine the reciprocal lattice vectors in case of bcc crystal. 3+2
7. (a) Prove why 5-fold or 7-fold rotational symmetries are not possible in perfect crystal structures. 3
- (b) A phosphorous doped silicon semiconductor (doping density; $10^{17}/\text{cm}^3$) is heated from 100°C to 200°C . Will the Fermi level stay as before or move? Comment. 2

Group - C

Answer any *one* of the following questions :

$$10 \times 1 = 10$$

8. (i) Discuss the limitations of Debye model of lattice specific heat capacity? What is Debye temperature?
- (ii) The resistivity of an intrinsic semiconductor is 4.5 ohm-m at 20°C and 2.0 ohm-m at 32°C . What is the energy band gap?
- (iii) What are Brillouin Zones? Obtain and construct first Brillouin Zones for a square lattice. $(2+1)+4+3$
9. (a) Derive the expression of the susceptibility of a diamagnetic substance. 5

- (b) What type of magnetic material is a superconductor? Find out the susceptibility of an ideal superconductor. 1+1

- (c) Inverse susceptibility ($1/\chi$) as a function of temperature, T for a material undergoing paramagnetic to ferromagnetic transition is given in the figure, where O is the origin. The Curie temperature (T_c) is expressed as the product of the Curie constant (C) and the Weiss molecular field constant (λ). Calculate the values of C and λ in CGS units. 3

