2022

5th Semester Examination

PHYSICS (Honours)

Paper : C 12-T

[Solid State Physics]

[CBCS]

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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 : 2×5=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 $T << \theta_D$ and $T >> \theta_D$.

(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 $\chi = \frac{c}{r-\theta}$, 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 : 5×4=20

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

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(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; $10^{17}/cm^3$) 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 : 10×1=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

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(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 (Tc) 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