2026

6th Semester Examination (CCFUP : NEP)

PHYSICS

Paper : MJ 12-T

(Single Core Major)

[Solid State Physics]

Full Marks : 60 Time : Three 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

Answer any ***ten*** questions : 2×10=20

1. A paramagnetic salt has a magnetic susceptibility of 8×10^{-4} at a temperature of 250 K. Calculate its magnetic susceptibility at 400 K assuming the material obeys Curie's law.

2. A plane makes intercepts of 1, 2, and 3 Å on the crystallographic axes of an orthorhombic crystal with lattice parameters in the ratio $a : b : c = 3 : 2 : 1$. Determine the Miller indices of this plane.

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

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$E = \frac{h^2 k(6k+5)}{8\pi^2 m}$. Find the effective mass of the electron in the crystal.

4. Explain the Hall effect and Hall voltage.

5. Write down the Clausius-Mossotti relation and define molar polarizability.

6. Explain the term, 'dielectric loss'. What is the reason behind this loss? 1+1

7. State the difference between perfect conductivity and superconductivity using the concept of the Meissner effect.

8. Write down the relation showing the temperature dependence of critical magnetic field (H_c). Find the value of H_c at the transition temperature. 1+1

9. A dielectric material has a polarizability $\alpha = 10^{-40}$ F.m^2. Calculate the polarization P when subjected to an electric field $E = 10^6$ V/m, and estimate the relative permittivity if the number density of molecules is $N = 10^{28}$ m^{-3}.

10. Derive the equivalent K- values of $\frac{4.2\pi}{a}$ in the 1st Brillouin zone for 1-D monoatomic lattice with lattice parameter a.

11. The mobility of electrons in a semiconductor is 0.12 m^{2}V^{-1}s^{-1} and electric field applied is 200 Vm^{-1}. Calculate drift velocity.

12. Differentiate between p-type and n-type semiconductors and also mention the positions of energy levels based on the band diagrams.

13. Is Cauchy relation sufficient to explain anomalous dispersion? Comment.

14. Monochromatic X-rays of wavelength 1Å are incident on a simple cubic crystal. The first order Bragg reflection from (311) plane occurs at angle of 30° from the plane. Calculate the lattice parameter of the crystal in Å.

15. What are acoustic and optical phonons?

Group - B

Answer any ***four*** questions : 5×4=20

16. (a) Show that Einstein's specific heat approaches zero as $T \to 0$. Comment on the physical significance.

    (b) State one major limitation of Einstein's theory.

    (c) A crystalline solid has Debye temperature $\theta_D = 400$K. Determine the Debye angular frequency. 2+1+2

17. (a) Discuss the basic features of the Kronig-Penny model.

    (b) A metal has thermal conductivity $K = 250$ Wm^{-1}K^{-1}, electrical conductivity $\sigma = 5\times10^7$ Sm^{-1} and temperature $T = 300$ K. Calculate the Lorentz number of the metal. 3+2

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18. (a) What is spontaneous polarization?

(b) Derive the Clausius-Mossotti equation expressing the relationship between dielectric constant and atomic polarizability. 1+4

19. (a) Prove why 5-fold or 7-fold rotational symmetries are not possible in perfect crystal structures.

(b) KBr (diatomic molecule) is a crystal having cubic structure. If its density is $2.75\times10^3\ kg/m^3$ and molecular weight is 119.01 gm/mol, calculate its lattice constant. 3+2

20. (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.

(b) A phosphorus-doped silicon semiconductor has donor concentration $5\times10^{21}\ m^{-3}$. Assuming complete ionization of donor atoms and electron mobility $0.12\ m^2V^{-1}s^{-1}$, calculate the electrical conductivity. 3+2

21. (a) Mention the differences between Type-I and Type-II superconductors.

(b) Define 'penetration depth' in superconductors and give the expression of 'penetration depth'. Also depict the variation of it with temperature.

(c) Write down the significance of 'critical magnetic field'. 2+2+1

Group - C

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

22. (a) Using quantum mechanical treatment, derive the expression for paramagnetic susceptibility and explain its dependence on temperature.

(b) What are ferromagnetic domains?

(c) A dielectric material has a number density of $N = 2\times10^{28}\ m^{-3}$ and atomic polarizability $\alpha = 1.5\times10^{-40}\ F.m^2$. Calculate its relative permittivity (ε_r) using the Clausius-Mossotti relation. (5+1)+2+2

23. (a) What do you understand by the effective mass of an electron in a crystal? Derive the expression of the effective mass (m^*) of an electron in a crystal.

(b) The energy-wave vector dispersion relation for a 1-D crystal of lattice constant a is given by $E(k) = E_0 - \alpha - 2\beta\cos ka$, where E_0, α, β are constants.

(i) Find the value of k at which the velocity of electron is a maximum.

(ii) Derive the energy difference between the top and the bottom of the energy band.

(iii) Derive the effective mass of the electron at the top of the band. (1+4)+(2+2+1)

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24. (a) What is the packing fraction in crystals? Find out the value of the packing factor for the BCC and FCC structures.

(b) Prove that the reciprocal lattice vectors of the FCC represent the basis vectors of a BCC real lattice.

(c) Define atomic scattering factor and geometrical structure factor. (1+2+2)+3+2

25. (a) Deduce the dispersion relation for a one-dimensional monoatomic crystal with lattice spacing a, in which the interaction between the nearest neighbours is harmonic. Find out the group velocity at the boundary of the first Brillouin zone. Also find an expression for the force constant between the nearest neighbours of the lattice (M is the mass of the atom).

(b) Explain the concept of phonon.

(c) A one-dimensional diatomic lattice has atomic masses $m_1 = 2\times10^{-26}$ kg, and $m_2 = 4\times10^{-26}$ kg, with force constant $C = 20$ N/m. Calculate the optical branch frequency at the centre of the Brillouin zone ($k = 0$). For the same diatomic lattice, determine the acoustic branch frequency at $k = 0$. (3+1+1)+2+3
