# 2024

## PHYSICS — HONOURS

**Paper : CC-14**

**(Solid State Physics)**

**Full Marks : 50**

*The figures in the margin indicate full marks.*

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

Answer ***question no.* 1** and ***any four*** questions from the rest.

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

(a) A crystal cannot diffract uv radiation. – Explain.

(b) What is Bravais lattice? What are the maximum number of Bravais lattices possible?

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

(d) What is Hall effect in solid?

(e) What are the basic assumptions of Kronig-Penny Model?

(f) For a certain gas molecule, the permanent dipole moment is 1.35 Debye unit. Calculate the orientational polarizability at room temperature.

(g) Distinguish between paramagnetic and ferromagnetic substances with examples.

**2.** (a) Show that the reciprocal lattice corresponding to an FCC lattice is a BCC lattice.

(b) Write down Bragg's law and explain its role for the determination of crystal structure.

(c) If the lattice parameter of a cubic lattice is $a$, then show that lattice constant (inter-planer spacing) is $d_{hkl} = \dfrac{a}{\sqrt{h^2 + k^2 + l^2}}$, where $(hkl)$ are the Miller indices.

(d) Find out the angle between two directions normal to (212) and (122) planes for a cubic crystal. 3+(1+1)+3+2

**3.** (a) What do you mean by lattice vibration and phonon?

(b) Show that the expression for the angular frequency (w) for diatomic lattice vibration is

$w^2 = \beta\left[\frac{1}{M}+\frac{1}{m}\right] \pm \beta\sqrt{\left[\frac{1}{M}+\frac{1}{m}\right]^2 - \frac{4\sin^2 ka}{mM}}$, where the symbols have their usual significance ($M > m$). Hence, show that for optical branch $k \to 0$, $w_+ = \sqrt{2\beta\left[\frac{1}{M}+\frac{1}{m}\right]}$

(c) At a very low temperature, the specific heat of rock salt is given by $C_v = A\left(\frac{T}{\theta_D}\right)^3$ according to Debye's $T^3$ law. Find the quantity of heat require to raise the temperature of 3 moles of rock salt from 10K to 50K. [Given $A$ = 464 cal/mol/K, $\theta_D$ = 281K] (1+1)+(4+2)+2

**4.** (a) From the Weiss field theory, find out the expression of magnetic susceptibility for a ferromagnetic material and show how does it vary above and below Curie temperature.

(b) The Curie temperature of iron is 1043K. If each iron atom has a magnetic moment of two Bohr magneton, calculate the values of the Weiss constant and the Curie constant. Assume that the saturation magnetisation of iron is $1.75\times10^6$ ampere/meter.

Iron is B.C.C with lattice parameter $a$ = 0.286 nm. Given $\mu_B = 9.2741\times10^{24}$ J/T

(3+1½+1½)+(2+2)

**5.** (a) Kronig-Penny Model gives a simplified form of energy levels in periodic lattice as

$$P\frac{\sin\alpha a}{\alpha a} + \cos\alpha a = \cos ka, \quad \text{where } P = \frac{mV_0 ab}{\hbar^2},\ \alpha^2 = \frac{2mE}{\hbar^2}$$

and symbols have their usual meaning.

(i) What is the physical significance of $P$?

(ii) By plotting the above equation as a function of '$\alpha a$', discuss the allowed and forbidden regions in the plot. (Assume a fixed value of $P$).

(iii) What is the energy of the lowest band at $k = 0$ in the limit $P \ll 1$?

(b) Consider the following ($E$ - $K$) relation for a cubic structure

$E = E_0 - \alpha - 2\gamma(\cos k_x a + \cos k_y a + \cos k_z a)$, where $\alpha$, $\gamma$, $E_0$ are constants and '$a$' is lattice constant.

(i) Find out the points for which the energy is minimum and maximum.

(ii) Obtain an expression of the effective mass for small values of '$k$' in terms of the parameters.

(1+3+2)+(2+2)

**6.** (a) Discuss different types of polarizability with appropriate examples.

(b) What do you mean by local field in case of a dielectric? Establish Clausius-Mosotti relation in the form $\frac{\epsilon_r - 1}{\epsilon_r + 2} = \frac{N\alpha_e}{3\epsilon_0}$, where the symbols have their usual significance.

(c) A solid dielectric has electronic polarizability of $10^{-40}$ $Fm^2$. If the internal dielectric field be a Lorentz field, what is the dielectric constant of the material? [Density = $3\times10^{28}$ atoms/$m^3$].

3+(1+3)+3

**7.** (a) Define mobility of free electrons in a metal. What is its relation with conductivity?

(b) Write down two important differences between Type-I and Type-II superconductors.

(c) Explain briefly the Meissner effect with suitable diagram.

(d) The critical fields at 6K and 8K for a NbTi alloy are ($7.616 \times 10^6$ and $4.284 \times 10^6$ A/m) respectively. Determine the transition temperature and critical field at 0 K. (1+1)+2+(2+1)+(1½+1½)

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