L

[This question paper contains 2 printed pages.]

Your Roll No.....

Sr. No. of Question Paper : 1934

Name of the course : B. Sc. Hons. (Physics)_NEP: UGCF-2022
Semester : IV-Semester
Name of the Paper : Solid State Physics
Unique Paper Code : 2222012402

Duration: 3 Hour **Maximum Marks: 90**

Instructions to the students:

(i) Attempt any five questions in total. Question No. 1 is compulsory.

(ii) All questions carry equal marks.

(iii) Use of non-programmable scientific calculators is permitted.

Q.1: Attempt any six of the following: (3 x 6 = 18)

(a) Draw $(\bar{2}31)$, (102) and $(1\bar{3}2)$ planes in a cubic crystal.

(b) The Bragg angle corresponding to the first order reflection from (1 1 1) planes in a crystal is 30^0, when X-rays of wavelength 1.75 Å are used. Calculate the interplanar spacing.

(c) The resistivity of a semiconductor is 1 Ω-m at room temperature. Calculate the mobility of conducting electrons if the density of conducting electrons is 10^{21} m^{-3}.

(d) The dispersion relation for phonons in a solid is given by $\omega^2(k) = \omega_m^2[5 - \cos(ka)]$. Find the group velocity of phonons in the large wavelength region.

(e) For aluminum, the heat capacity at constant volume C_v and at 30 K is 0.81 J/mol-K and the Debye temperature is 375 K. Estimate the specific heat at (i) 50 K and (ii) 425 K.

(f) A ferromagnetic material has a Curie temperature of 100 K. If its magnetic susceptibility at 300 K is 2×10^{-3}, find its magnetic susceptibility at 200 K using the Curie–Weiss law.

(g) Explain why the dielectric constant of water is 81 at zero frequency and 1.8 at frequency in visible range.

Q.2: (a) What is packing fraction? Also determine the value of packing fraction of body centered cubic (BCC) structure. (6)

(b) Determine the reciprocal lattice vectors of the reciprocal lattice defined by the primitive translation vectors $\vec{a} = 5\hat{\imath} + 5\hat{\jmath} - 5\hat{k}$, $\vec{b} = -5\hat{\imath} + 5\hat{\jmath} + 5\hat{k}$, $\vec{c} = 5\hat{\imath} - 5\hat{\jmath} + 5\hat{k}$, where $\hat{\imath}$, $\hat{\jmath}$ and $\hat{k}$ are the unit vectors along X, Y and Z axes. (6)

(c) Show that BCC lattice is reciprocal to a FCC lattice. (6)

Q.3: (a) Describe direct and indirect band gaps. Obtain an expression of effective mass of an electron in a band. Explain the concept of negative effective mass. (12)

(b) Explain the concept of critical magnetic field in a superconductor. The critical temperature of a superconducting material is 3.7 K. The maximum critical magnetic field of this material is 0.0306 Tesla. Calculate the critical magnetic field at 2 K. (6)

Q.4: (a) For one dimensional diatomic crystal with atomic masses M (heavier) and m (lighter), force constant β and lattice constant a:

(i) Show that the phonon dispersions have two solutions given as

$$\omega(k) = \sqrt{\frac{\beta}{mM}}.\sqrt{m + M \pm \sqrt{m^2 + M^2 + 2mMcos(ka)}}$$

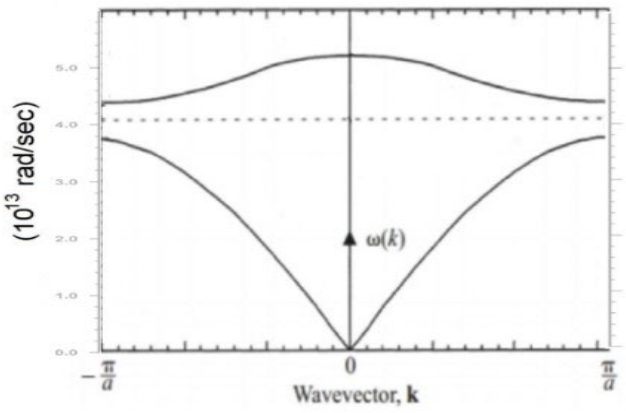
(ii) Sketch the two $\omega(k)$ as a function of k ($\frac{-\pi}{a} \leq k \leq \frac{+\pi}{a}$), and label each of them as "acoustic" or "optical" phonons.

(iii) Find the two frequencies at the edge of the Brillouin zone, i.e. find $\omega(k)$ where $k = \pi/a$ and also find the expression of the energy difference (i.e., the acoustic-optical phonon bandage) between these two frequencies.

(iv) Evaluate phonon group velocity v_g for these two phonon modes at $k = \pi/a$.

(12)

(b) A plot of phonon dispersion relation is shown in the figure below. What is the shortest wavelength in (nm) if the lattice constant is a = 5.5Å.



(6)

Q.5 (a) Obtain an expression for the diamagnetic susceptibility of a material using Langevin's theory. What is the significance of negative susceptibility? (12)

(b) Differentiate between soft and hard ferromagnetic materials with the help of a hysteresis loop. Give one example of each type. (6)

Q.6 (a) Derive the relation $\overrightarrow{E_{Loc}} = \vec{E} + \frac{\vec{P}}{\epsilon_0}$ for local electric field in solids, where the symbols have usual meanings. Explain the significances of electric fields $\overrightarrow{E_{Loc}}$ and $\vec{E}$. (12)

(b) Derive relations between (i) electric susceptibility and dielectric constant, and (ii) electric susceptibility and polarizability. (6)

Charge of an electron = 1.6 X 10^{-19} C

Gas Constant R = 8.314 J mol^{-1} K^{-1}