[This question paper contains 4 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 5597 **J**

Unique Paper Code : 2222012402

Name of the Paper : Solid State Physics

Name of the Course : **B.Sc. Hons.-(Physics)_NEP:UGCF-2022**

Semester : IV

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt any five questions in total. Question No. 1 is compulsory.
3. All questions carry equal marks.
4. Use of non-programmable scientific calculators is permitted.

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

(a) Draw (221) and (110) planes in a cubic crystal. Also, show [111] direction in a cubic unit cell.

(b) An X-ray beam of wavelength 1.54 Å is diffracted from the (100) planes of a solid with a cubic lattice of lattice constant 3.05 Å. Find the Bragg's angle at which the first-order diffraction occurs.

(c) Hall coefficient of a specimen of a strong n-type silicon is 3.66×10^{-4} m^3C^{-1}. The resistivity of the specimen is 8.93×10^{-3} m. Find the mobility and density of the charge carriers.

(d) Calculate Einstein's frequency for copper (Cu) metal that has an Einstein's température θ_E=230° K.

(e) Discuss various sources of polarizability in a dielectric.

(f) Explain the B-H curve of a ferromagnetic material.

(g) Explain Meissner's effect in the superconductor.

2. (a) Explain Ewald's construction and derive Bragg's law $2\vec{K}.\vec{G} + G^2 = 0$ for X-ray diffraction in a reciprocal lattice, where the symbols have their usual meanings. (12)

(b) Calculate the packing fraction for face-centered cubic (FCC) crystal. (6)

3. (a) For the Kroning-Penney model of electron behaviour in solids, derive the relation $P\frac{sin(\alpha a)}{\alpha a} + cos(\alpha a) = cos(ka)$ where P is proportional to the barrier strength (height and width) between adjacent lattice atoms, a is the lattice constant, k is the wavenumber, and $\alpha = \sqrt{\frac{2mE}{\hbar^2}}$.. Sketch the general behaviour of this relation as a function of αa clearly indicating the value of ?αa = 0

and the limiting case $\alpha a \to \infty$. By considering the above condition clearly indicate on your sketch the ranges of αa that correspond to allowed energy bands. (12)

(b) Show that in the limit of $P \to \infty$ the relation leads to discrete allowed energy given by $E_n = \dfrac{n^2\hbar^2\pi^2}{2ma^2}$. (6)

4. (a) Derive an expression for the lattice specific heat of a solid based on the Debye model and demonstrate that it varies as T^3 at low temperatures. (12)

(b) Calculate the number of optical and acoustical phonon branches for a NaCl crystal, containing two atoms per primitive unit cell. (6)

5. (a) Describe the Langevin theory of para-magnetism and explain Weiss modification in this theory assuming the existence of an internal molecular field. (12)

(b) A paramagnetic salt contains 10^{28} ions/m^3, each with magnetic moment 9.27 x 10^{-24} A-m^2. Calculate paramagnetic susceptibility produced in a uniform magnetic field H = 10^6 A/m at 300° K. (6)

6. (a) Define the term "Local electric field" at an atom. Deduce Lorentz relation for E_{Loc} inside a dielectric. (12)

(b) Draw a typical P-E hysteresis curve for a ferroelectric material and give one example. (6)

Charge of an electron = 1.602×10^{-19} C

Planck's Constant = 6.62×10^{-34} J-s

Boltzmann Constant = 1.38×10^{-23} J/K

$\mu_0 = 4\pi \times 10^{-7}$ Kg m s^{-2} A^{-2}