Registration Number:
Date & Session:

ST JOSEPH'S UNIVERSITY, BENGALURU -27
M.Sc. Physics – 4th SEMESTER
SEMESTER EXAMINATION: APRIL 2024
(Examination conducted in May / June 2024)

PH0120 – Solid state Physics
(For current batch students only)

Time: 2 Hours **Max Marks: 50**

This paper contains THREE printed pages and TWO parts

PART-A

Answer any FIVE questions. Each question carries SEVEN Marks.

[5 x 7 = 35]

1. (a). Obtain an expression for the interplanar spacing for planes of the (h k l) type in the case of cubic structure.

   (b). Construct first two Brillouin Zones encompassing the given lattice points within a 2D lattice structure.

   (c). Given that $\vec{k}$ represents the wavevector of incident light ($|\vec{k}| = \frac{2\pi}{\lambda}$, where λ is the wavelength of light) $\vec{G}$ is a reciprocal lattice vector, express Bragg's law as $2\,\vec{k}.\vec{G} + \vec{G}^2 = 0$. Determine the boundary values that define the boundaries of the first and second Brillouin zones. [3+2+2]
2. Using the Kronig-Penney model, explain the electron in a one-dimensional periodic potential. How does it lead to formation of energy bands in solids?
3. (a). Explain the single-particle tunneling effect for Superconductor-Insulator-Superconductor (SIS) system Using current-voltage (I-V) curve.

   (b). Demonstrate mathematically the perfect diamagnetic properties exhibited by superconductors. [4+3]
4. Describe the Wiess molecular field theory of ferromagnetism and obtain the Cuire-Weiss law.
5. Find the expression relating the macroscopic dielectric constant with microscopic polarizabilities by driving the Classius-Mosotti relation.
6. In a linear chain, the lattice dynamics of a diatomic chain with masses M and m (where $M>m$) are arranged alternately by springs with a force constant K at a nearest neighbor distance of a. The dispersion relation connecting ω and k for a one-dimensional diatomic lattice with nearest neighbor interactions is expressed as

$$\omega^2 = K\left(\frac{1}{M}+\frac{1}{m}\right) \pm K\left[\left(\frac{1}{M}+\frac{1}{m}\right)^2 - \frac{4sin^2 qa}{Mm}\right]^{\frac{1}{2}}$$

(i). Obtain frequency-wavevector relation for both acoustics and optical modes.

(ii). Plot the dispersion curve, ω versus q for one dimensional diatomic lattice $(M > m)$ in reduced zone scheme. Show that the both acoustic and optical branches in dispersion curve meet the zone boundary normally. [5+2]

7. (a). How does the paramagnetic susceptibility of a substance vary with temperature?

   (b). Describe the spontaneous polarization of Barium Titanate crystal.

   (c). Explain the critical magnetic field in a superconductor. How does the critical magnetic field vary with temperature in Type I and Type II superconductor? [2+3+2]

PART-B

Answer any THREE questions. Each question carries FIVE Marks.

[3 x 5 = 15]

8. Find the total polarizability of CO_2, if its susceptibility is 0.985 x 10^{-3}. Density of carbon dioxide is 1.977 kg/m^3.
9. A paramagnetic substance contains 10^{28} ions/m^3 with magnetic moment of one Bohr magnetron. Calculate the paramagnetic susceptibility and the magnetization produced in a uniform magnetic field of 10^6 A/m, at room temperature.
10. A superconductor has a critical temperature of 7.26 K at zero magnetic field and a critical field of 8 x 10^5 A/m at 0K. Find the critical field at 5K.
11. (a). The distance between consecutive (1 1 1) planes in a cubic crystal is 2 Å. Determine the lattice constant.

    (b). The Debye temperature of diamond is 2400K. Determine the highest possible vibrational frequency at 5K.

    (c). The hall coefficient of a certain silicon specimen was found to be $-7.35 \times 10^{-5} m^3 C^{-1}$ from 100 to 400 K and the electrical conductivity was found to be 200 $\Omega^{-1}m^{-1}$. Calculate the density and mobility of charges carriers. [1.5+1.5+2]

List of Physics Constants

Speed of light in vacuum (c)	2.997925×10^{8} ms^{-1}
Charge of electron (e)	1.6021×10^{-19} C
Rest mass of electron (m)	9.109×10^{-31} kg
Atomic mass unit (m_u)	1.6604×10^{-27} kg
Electron radius (r_e)	2.828×10^{-15} m
1 Angstrom unit (Å)	10^{-10} m
Avogadro's number (N_A)	6.02252×10^{26} $kmol^{-1}$
Boltzmann constant (k_B)	1.38054×10^{-23} jK^{-1}
Thermal energy at 300K (k_BT)	0.0258 J
Planck's constant (h)	6.626×10^{-34} Js
Permeability of free space (μ_o)	$4\pi \times 10^{-7}$ Hm^{-1}
Permittivity of free space (ε_o)	8.854×10^{-12} Fm^{-1}
Rydberg constant for Hydrogen (R_H)	1.0967758×10^{7} m^{-1}
Universal gas constant ($Ru = N_Ak_B$)	8.3143×10^{3} $Jkmol^{-1}K$