b) Find the phase difference for acoustic and optical modes:

i) between two different ions within a definite primitive cell, and

ii) between the same ion within the two adjacent primitive cells, for two different cases when (A) $ka = 0$, and (B) $ka = \pi$.

c) Draw the instantaneous positions of two ions for acoustic and optical modes when (A) $ka = 0$, and (B) $ka = \pi$. 4+(2+2)+2=10

3. a) Show that in thermodynamic equilirbium, magnetic susceptibility, χ, can be defined as

$$\chi = -\frac{\mu_0}{\mathcal{V}} \frac{\partial^2 \mathcal{F}}{\partial B^2}$$

Symbols have their usual meaning.

b) State the Bohr-van Leeuwen theorem.

c) Using the classical Hamiltonian of a charged particle,

$$H_c(r, p) = \frac{1}{2m}\left[p - qA(r)\right]^2 + q\phi(r)$$

explain the Bohr-van Leeuwen theorem.

Symbols have their usual meaning.

d) How do you explain this theorem from physical point of view. 2+1+5+2=10

Ex/SC/PHY/UG/DSE/TH/01/A2/2023

B. Sc. Physics (Hons.) Examination, 2023

(3rd Year, 1st Semester)

Condensed Matter Physics

Paper – DSE 01 A2

Time : Two hours Full Marks : 40

(20 marks for each group)

Use separate answerscripts for each group.

Group – A

Answer ***any Four*** questions. 4×5=20

1. What is Wigner Seitz cell? Draw a two-dimensional square lattice. With proper drawing explain the steps to construct a Wigner Seitz cell. What is Wigner Seitz cell in reciprocal space called? 1+3+1=5

2. What do you mean by symmetry operation? Name the symmetry operations and corresponding symmetry elements. If the position cooridnate of an element is (x, y, z) then what will be its position coordinate after mirror operation where mirror plane is perpendicular to Y-axis. Explain with proper drawing. 1+2+2=5

3. What properties a set of elements, forming a group, should follow? Differentiate between point group and space group. Draw and explain Glide and Screw symmetry. 2+1+2=5

[Turn over

4. Explain how reciprocal crystal is formed from real lattice. Write basis vectors of reciprocal lattice in terms of basis vectors of real lattice? Why reciprocal lattice is important in the context of X-ray diffraction? 2+2+1=5

5. What is the basic difference between Laue formalism and Bragg formalism for X-Ray diffraction? What is Ewald sphere? What is its significance in X-ray diffraction? Name different X-ray diffraction methods used, mentioning the fixed and variable parameters in each case. 1+1+1+2=5

6. What are the classifications of nanomaterials based on their dimension? What are the unique characteristics of nanomaterials? Explain why nanoparticles are more reactive compared to their bulk counterpart? 1+2+2=5

Group – B

Answer ***any Two*** questions. 2×10=20

1. a) The total potential energy of the whole crystal can be expressed as

$$V = \frac{1}{2}\sum_{R,R'}{}' \Phi\left(R - R' + u_R - u_{R'}\right),$$

where the symbols have their usual meaning. Now employing the three-dimensional Taylor series expansion show that

$$V \approx \frac{1}{2}\sum_{R,R'}{}' \Phi\left(R-R'\right) + \frac{1}{4}\sum_{R,R'}{}' \left[\left(u_R - u_{R'}\right)\cdot\nabla\right]^2 \Phi\left(R-R'\right).$$

b) Consider a one-dimensional Bravais lattice of monoatomic basis in which the mass of the atoms is M and the nearest neighbours interact through the spring constant $\mathcal{K}$ such that the total potential of the system is

$$V_{\text{Harm}} = \frac{1}{2}\mathcal{K}\sum_{n}\left(u_n - u_{n+1}\right)^2$$

Now show that the dispersion relation for the travelling wave solution is

$$\omega(k) = 2\sqrt{\frac{\mathcal{K}}{M}}\left|\sin\left(\frac{ka}{2}\right)\right|.$$

c) What will be expression of group velocity of the above dispersion relation? 4+4+2=10

2. Consider a one dimensional Bravais lattice with diatomic basis in which the masses of two atoms are the same, M and where the nearest neighbours interact alternately through the spring constants $\mathcal{K}$ and $\mathcal{G}$ such that the total potential of the system is

$$V_{\text{Harm}} = \frac{\mathcal{K}}{2}\sum_{n}\left(u_n^A - u_n^B\right)^2 + \frac{\mathcal{G}}{2}\sum_{n}\left(u_n^B - u_{n+1}^A\right)^2$$

Symbols have their usual meaning.

a) Solving the corresponding equation of motion, show that the dispersion relations are

$$\omega_{\pm}^2 = \frac{\mathcal{K}+\mathcal{G}}{M} \pm \frac{1}{M}\sqrt{\mathcal{K}^2 + \mathcal{G}^2 + 2\mathcal{K}\mathcal{G}\cos(ka)}\,.$$