3. **[CO3]** 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 meanings.

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

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

(b) Draw the dispersion curves.

(c) Find the expression of band gap (value of minimum separation between the two curves).

(d) When $\mathcal{K} = \mathcal{G}$, compare the dispersion relations with that of the one-dimensional Bravais lattice with monoatomic basis, discuss how two branches (acoustic and optical) in the Brillouin zone of the diatomic basis do collapse into a single (acoustic) branch in the first Brillouin zone of the monoatomic basis. 5+1+1+3=10

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BACHELOR OF SCIENCE EXAMINATION, 2025

(3rd Year, 1st Semester)

PHYSICS

PAPER : DSE 01 A2

(Code : UG/DSE/PHY/TH/01/A2

(Condensed Matter Physics)

Time : *Two Hours* *Full Marks* : 40

20 marks for each Group.
Use separate answer scripts for each Group.

GROUP—A

Answer ***any two*** questions : 10×2=20

1. **[CO1]** *(a)* How many crystal structure are there in three-dimensions? Mention each with their lattice parameters.

(b) Describe symmetry operation and symmetry elements and give examples. How many rotational symmetry axis and mirror symmetry planes are possible in a cube?

(c) Draw stereographic projection of a vertical four-fold rotoinversion. Draw each step to explain.

(d) Obtain the Laue condition for diffraction from a crystal. [(1+3)+(3+1)+3+4=15

(OR)

[CO1] *(a)* A crystal has lattice constants of 1 Å, 2Å and 3Å. A plane (321) cuts an intercept of 1Å along *x*-axis. Find the intercepts along other axes. Draw and explain it in detail.

(b) Write and describe the properties, the symmetry elements constituting a group should follow.

(c) What are the two nomenclatures used to describe point groups. Give the notation in both nomenclatures for a mirror plane perpendicular to four-fold rotational axis.

(d) Explain how reciprocal lattice can be constructed from real lattice. How the Bragg's condition in reciprocal space. How to draw Ewald sphere based on it? [3+3+(1+2)+(3+1+2)=15]

2. **[CO4]** What are the unique characteristics of nanomaterials. Describe plasmons. Explain how surface plasmons are important in nanomaterials. 2+1+2=5

(OR)

What are the classifications of nanomaterials based on their dimensions? Find out the surface to volume ratio of a sphere of 100 nm diameter. Explain why nanoparticles are more reactive compared to their bulk counterpart? 1+2+2=5

GROUP—B

Answer ***any two*** questions : 10×2=20

1. **[CO2]** *(a)* Using the expression of current density, $j = -ne\bar{v}$, show that according to Drude model, dc electrical conductivity can be expressed as

$$\sigma_0 = \frac{ne^2\tau}{m}.$$

(b) Consider the heat conduction through an insulated solid rod of uniform cross-section. Now finding the net energy flux from hot to cold end, obtain the expression of thermal conductivity for the three-dimensional system.

(c) Describe Wiedemann-Franz law. 3+5+2=10

2. **[CO2]** *(a)* State the assumptions of the Summerfeld model.

(b) Prove the Sommerfeld expansion,

$$\int_0^\infty f(E)\frac{\partial F}{\partial E}dE = F(E_F) + \frac{\pi^2}{6}(k_B T)^2\left(\frac{\partial^2 F}{\partial E^2}\right)_{E_F},$$

where $f(E)$ is the Fermi-Dirac distribution functions and *F(E)* is a regular functions and such that $F(0) = 0$.

(c) Using the Sommerfeld expansion, show that the energy of Fermi level at room temperature T can be expressed as

$$E_F(T) \approx E_F(0)\left[1 - \frac{\pi}{12}\left(\frac{T}{T_F}\right)^2\right].$$

Symbols have their usual meanings. 2+4+4=10