Five Year Integrated M.Sc. Examination, 2023-2024
Semester - VII
Paper: PH-4-7-2

Time: Four Hours | Subject: Material Science | Full Marks: 80

Questions are of values as indicated in the margin

GROUP -A

Answer any **ten** from Group -A

1. Answer any **ten** questions

$10 \times 2 = 20$

(a) Calculate the minimum distance between two lattice points of a BCC lattice with lattice constant a.

(b) Explain the construction of Wigner-Seitz unit cell with the help of appropriate diagram.

(c) Show that the first derivative of wave function satisfies following relation across a potential $V(x) = \alpha\delta(x)$ situated at $x = 0$:

$$\lim_{\epsilon\to 0}\left[\frac{d\psi}{dx}\right]_{0+\epsilon} - \lim_{\epsilon\to 0}\left[\frac{d\psi}{dx}\right]_{0-\epsilon} = \frac{2m\alpha}{\hbar^2}\psi(0)\,.$$

(d) Draw the the dispersion relation diagram for the optic and acoustic modes of a diatomic linear lattice.

(e) What do you mean by normal modes and normal frequencies ?

(f) Briefly discuss the origin of ferromagnetism and paramagnetism.

(g) What are the two models for gas adsorption and what is the difference between the two?

(h) Explain the growth of nanoparticles inside dendrimers.

(i) Show the splitting of energy levels in quantum dots due to the quantum confinement effect.

(j) What is the difference between naturally occurring and manmade nanoparticles? Give examples.

(k) Write down the expression for $\frac{1}{d^2}$ for cubic and hexagonal crystal classes.

(l) Classify the following nanomaterials on the basis of their dimension. (i) CdSe quantum dot, (ii) Carbon nanotube, (iii) Core-shell nanoparticle, (iv) Graphene based composite, (v) Porous composite electrode, (vi) Carbon-coated nanoplate

GROUP -B

Answer any **twelve** from Group-B

$12 \times 5 = 60$

2. What is a reciprocal lattice? Define the reciprocal lattice vectors $\vec{b_1}$, $\vec{b_2}$ and $\vec{b_3}$ in terms of the primitive vectors $\vec{a_1}$, $\vec{a_2}$ and $\vec{a_3}$ in direct space. Hence prove that

$$\vec{b_1}.(\vec{b_2} \times \vec{b_3}) = \frac{(2\pi)^2}{\vec{a_1}.(\vec{a_2} \times \vec{a_3})}.$$

1+2+2=5

3. (a) If the primitive translation vectors of a two-dimensional lattice are $\vec{a} = 3\hat{i} - \hat{j}$ and $\vec{b} = \hat{i} + 2\hat{j}$, find the reciprocal lattice vectors.

   (b) Suppose a plane intersects the coordinate axes at $x = 3$, $y = -2$ and $z = 3$ in units of the lattice constants. Determine the Miller indices of this family of lattice planes.

3+2=5

4. Prove the equivalence between Bragg's law and Laue's condition.

5

5. Show that the spacing between these lattice planes is $d = 2\pi/|G_{\min}|$ where $G_{\min}$ is the minimum length reciprocal lattice vector in this normal direction.

5

6. Derive the dispersion relation for the longitudinal oscillations of a one-dimensional mass-and- spring crystal with N identical atoms of mass m, lattice spacing a, and spring constant κ (motion of the masses is restricted to be in one dimension).

5

7. Using the expression of dispersion relation for one dimensional monatomic chain, show that the mode with wavevector k has the same pattern of mass displacements as the mode with wavevector $k + 2\pi/a$. Hence show that the dispersion relation is periodic in reciprocal space (k-space). How many different normal modes are there?

4+1=5

8. Assume a scattering time τ and use Drude theory to derive an expression for the conductivity of a metal.

5

9. (a) Discuss the application of nanomaterials in water purification.

   (b) How do two colloidal particles with electrical double layers interact? Explain such interactions using a suitable figure.

2+3=5

10. (a) Explain what happens when the ionic surfactant, $[(C_{16}H_{33})N(CH_3)_3]Br$, taken above the critical micellar concentration is dissolved in chloroform.

    (b) Discuss a method for the synthesis of zinc sulfide nanoparticles with controlled morphology. How can you restrict the particle sizes in the synthesis?

2+3=5

11. (a) What are capping agents? Give example. Discuss their role in the syntheses of nanomaterials.

    (b) Write the basic principle of ball-mill technique and sketch the different types of ball-mill apparatus used in the synthesis of nanomaterials.

2+3=5

12. (a) What is the advantage of scanning tunneling microscopy over scanning electron microscopy? How does it expand the range of samples that can be investigated?

    (b) Explain top-down and bottom-up approaches in the syntheses on nanomaterials.

    (c) What is the difference between coagulum and floc?

2+2+1=5

13. (a) Briefly discuss a technique for the synthesis of highly pure indium phosphide based nanomaterials.

    (b) Starting from the same precursors, how can you synthesize hollow and dense particles? How is it possible to generate porosity inside a nanoparticle?

2+3=5

14. (a) Explain Stern layer and Diffuse layer in connection to a colloidal system. Using a potential vs. distance from the colloid profile locate the (i) surface potential, (ii) Zeta potential, (iii) Stern layer and (iv) Diffuse layer.

    (b) In the treatment of cancer using nanoshells which property of the material is utilized and how do they act on the tumor sites?

3+2=5

15. (a) What are the two phases in following colloidal systems: (i) milk, (ii) paint, (iii) fog and (iv) opal?

    (b) With a suitable diagram explain the synthesis of nanomaterials by inert gas condensation technique (IGCT).

2+3=5