Five Year Integrated M.Sc. Examination, 2022-2023
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) Primitive lattice vectors of a two-dimensional lattice are given by

$$\vec{a_1} = \cos\theta\,\hat{i} + \sin\theta\,\hat{j},\ \vec{a_2} = -\sin\theta\,\hat{i} + \cos\theta\,\hat{j}\,,$$

where θ is a constant. Find the reciprocal lattice vectors.

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

(c) Draw the lattice planes represented by the Miller indices $(1, 2, 1)$ and $(\bar{1}, 1, 1)$.

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

(e) Using appropriate diagram prove that two adjacent lattice points on a honeycomb lattice are not equivalent. Hence identify two equivalent points on this lattice.

(f) State the assumptions of the Debye model of heat capacity of a solid.

(g) What are the main aims of chemical modification of nanoparticle surface?

(h) Discuss the role of nanoparticles in targeted drug delivery.

(i) Sketch the set-up of a spray pyrolysis system.

(j) Is color a size dependent property? – Explain.

(k) What is zeta potential? Show its relationship with surface potential using a suitable plot.

(l) Draw a schematic representation of the working of a transmission electron microscope.

GROUP -B

Answer any **twelve** from Group-B

$12 \times 5 = 60$

2. Define lattice, unit cell and primitive unit cell with appropriate diagrams.

5

3. Calculate the specific heat of solids in three dimensions following Einstein's theory.

5

4. Consider a diatomic chain in one dimension. Write the equations of motion for atoms and find the dispersion relation.

5

5. We apply a magnetic field along the z-direction to a planar (two-dimensional) sample that sits in the xy plane. The sample has width W in the y-direction, length L in the x-direction and we apply a current I along the x-direction.
Suppose we measure a Hall voltage V_H. Express the Hall resistance $R_{xy} = V_H/I$ as a function of magnetic field. Does R_{xy} depend on the geometry of the sample? Also express R_{xy} in terms of the Hall coefficient R_H.

5

6. State Bloch theorem for periodic potential. Consider an electron moving through a one-dimensional periodic lattice of periodicity a. For which value of n, $\psi(x) = A \exp\left(i\left[\frac{\pi x}{a} + \cos(\frac{n\pi x}{a})\right]\right)$ represents an energy eigenfunction of this system that is consistent with the Bloch's theorem?

5

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

5

8. Consider the motion of an electron in periodic potential given by

$$V(x) = \alpha \sum_{n=-\infty}^{n=\infty} \delta(x - na)\,,$$

where $V(x + a) = V(x)$ and $\delta(x)$ is Dirac delta function.

(a) Write down the Schrödinger equation for the electron in the aforesaid periodic potential.

(b) If $\psi(x)$ represents a single electron wave-function, show that

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

2+3=5

9. (a) Illustrate with an appropriate model that the surface to volume ratio increases when a bulk material is broken down into smaller particles.

(b) Outline a synthetic route for the preparation of dendrimer. How can they be used to synthesize nanoparticles?

2+(2+1)=5

10. (a) Explain quantum confinement effect.

(b) What are the cell parameters of cubic and hexagonal crystals? Write down the expression for $\frac{1}{d^2}$ for these crystal classes.

2+(1+2)=5

11. (a) Briefly discuss about carbon based nanomaterials.

(b) What is Ostwald's Ripening? Draw the La Mer model for monodisperse colloid growth.

2+(1+2)=5

12. (a) What is molecular beam epitaxy (MBE)? What are the two epitaxy techniques?

    (b) Write down the working principle in MBE. Give example of two different types of materials that can be prepared by MBE.

(1+1)+(2+1)=5

13. (a) What are colloids? Identify the two phases in following colloidal systems: (i) smoke, (ii) shaving cream, (iii) styrofoam and (iv) butter.

    (b) Illustrate the role of capping agents in the synthesis of nanomaterials using appropriate example.

(1+2)+2=5

14. (a) Briefly describe a methodology for the synthesis of size-controlled ZnS nanoparticles.

    (b) In inert gas condensation technique explain the role of inert gas (i) type, (iii) pressure and (iii) flow rate on the size of the resulting particles.

2+3=5

15. (a) What are the drawbacks of using titanium and stainless steel alloys in medical implantations?

    (b) Write down the basic principle of energy dispersive X-ray spectroscopy.

    (c) Write down Scherrer's equation explaining the various terms appearing in it.

2+2+1=5