Five Year Integrated M.Sc. Examination, 2021-2022
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
Answer question number **one** and any **six** from the rest

1. Answer any **ten** questions

$10 \times 2 = 20$

(a) Define Fermi energy.

(b) Show that the reciprocal lattice of BCC lattice is FCC lattice.

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

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

(e) Determine the Miller indices of a plane whose intercepts on x, y and z axis are $a/2$, $-a/8$ and $a/6$ respectively.

(f) Briefly discuss the origin of ferromagnetism and anti-ferromagnetism.

(g) What is the advantage of scanning tunneling microscopy over scanning electron microscopy and how does it expand the breadth of samples that can be analyzed?

(h) Using an appropriate example discuss a technique for the synthesis of nanostructures with anisotropy.

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

(j) What is a hydrogen fuel cell and why it is advantageous over traditional fuels?

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

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

2. (a) Show that the intercepts with the crystal axes of a lattice plane are inversely proportional to the Miller indices of the plane.

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

(c) Consider a monatomic chain in one dimension. Write the equations of motion for atoms and find out the dispersion relation.

3+3+4=10

3. (a) Draw the dispersion relations for vibrations of the one-dimensional diatomic chain. Hence identify the optical and acoustic branches.

   (b) Show that each lattice point in an fcc lattice has twelve nearest neighbours, each the same distance from the initial point. What is this distance if the conventional unit cell has lattice constant a?

   (c) Derive Laue's condition for X-ray diffraction by a crystal.

(2+1)+(2+1)+4=10

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

   (b) Define Hall coefficient.

   (c) Estimate the magnitude of the Hall voltage for a specimen of sodium in the form of a rod of rectangular cross-section $5\,mm$ by $5\,mm$ carrying a current of $1A$ down its long axis in a magnetic field of $1\,T$ perpendicular to the long axis. The density of sodium atoms is roughly $1\,gm/cm^3$, and sodium has atomic mass of roughly 23. You may assume that there is one free electron per sodium atom (sodium has valence 1).

4+2+4=10

5. (a) Calculate the specific heat of solids in three dimensions following Einstein's theory.

   (b) Obtain Dulong-Petit's law from Einstein's expression for heat capacity in high temperature limit.

   (c) What are the limitations of Einstein's theory ?

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

4+2+2+2=10

6. (a) Establish the effect of nano-scale dimension on the surface area of a material. State and briefly explain a property which is highly influenced due to such effect.

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

   (c) Discuss the role and importance of nanomaterials in the area of medicine.

4+3+3=10

7. (a) State and derive Bragg's law.

   (b) A compound is irradiated with X-rays from an external source. Explain the difference processes that will be triggered due to such external stimulation and what information can be obtained about the sample from such studies.

   (c) How do two colloidal particles with electrical double layers interact? Explain such interactions using a suitable figure. What are the various ways to modulate these mutual interactions?

3+3+4=10

8. (a) Precipitates are usually digested, preferably overnight, to obtain bigger sized particles. What is the mechanism behind such process and what takes place during the process? Explain it with a suitable model.

   (b) Is color of a nanomaterial a size dependent property? Establish your answer with appropriate theory and example.

   (c) What are prerequisites of sample preparation prior to collection of images using transmission and scanning electron microscopy and why?

   (d) Justify whether the following statements are true or false.

      i. Helium is preferred over argon for nanomaterials production using inert gas condensation technique.

      ii. High purity nanomaterials are obtained through ball-milling technique.

3+3+2+2=10

9. (a) What are the preferred techniques that will be employed for the syntheses of the following nanomaterials? Give an outline of the techniques very briefly.
(i) Indium phosphide and (ii) Platinum nanowires

(b) Starting with the same precursors, illustrate a process for the synthesis of hollow and dense particles.

(c) What are dendrimers and what are the types of nanoparticles that can be synthesized employing them? What are the forces leading to interactions inside a dendrimer structure? Illustrate an application of the dendrimers.

(d) Discuss the application of Zeta Potential in pharmaceutical and paint industry.

3+2+3+2=10