Ref. No.: Ex/Met/BS/B/T/224/2025

B.E. METALLURGICAL and MATERIAL ENGINEERING

SECOND YEAR SECOND SEMESTER EXAMINATION – 2025

Subject: Material Science

Time: Three Hours **Full Marks:** 100

Answer the following Questions:

1. a) Define linear and planar density of atoms in case of crystalline structure. Deduce the relationship for planar density of atoms in case of (110) plane of FCC structure. **[CO1]** 4+3 = 7

   b) Find the fraction of vacant space for a unit cell of pure iron at room temperature. **[CO1]** 4

   c) Find the theoretical density of copper. Given: Atomic mass unit of Cu = 63.546, Atomic radius of Cu = 0.128 nm. **[CO1]** 3

   d) By giving a sketch of (111) plane in a FCC unit cell draw an intersecting 111 type plane with common axes and show the line of intersection and give the indices of these two intersecting planes. **[CO1]** 6

OR

2. a) Compute the interplanar spacings for (111) and (211) sets of planes for α-Fe. Given: Atomic radius of α-Fe = 0.1241 nm. **[CO1]** 4

   b) Cr has a BCC crystal structure. If the angle of diffraction for the (311) set of planes occurs at 75.99° (first-order reflection) when monochromatic X-radiation having a wavelength of 0.1659 nm is used, compute **(i)** interplanar spacing for this set of planes, and **(ii)** the atomic radius for the Nb atom. **[CO1]** 4+4 = 8

   c) Niobium has an atomic radius of 0.1430 nm and a density of 8.57 g/cm^3. Determine whether it has an FCC or BCC crystal structure. **[CO1]** 5

   d) What is Wiess Zone law? **[CO1]** 3

3. a) Draw a binary phase diagram of two metals, A and B, having no solid solubility of A in B and limited solid solubility of B in A. Consider that A and B have complete solubility in each other in the liquid state and B has higher melting point than A. Give an example of such system and make a correspondence of the system with this phase diagram. **[CO1]** 5+2+2 = 9

   b) Define Degrees of Freedom. Find the degrees of freedom at the lowest melting point of the above system of A and B (3a). **[CO1]** 2+2 = 4

   c) What is a peritectic reaction and Give an example of such reaction. Find the degrees of freedom of this reaction. Why does the reaction not go to completion? **[CO1]** 2+2+3 = 7

OR

4. a) What is electron compound? Give three examples of such compound. **[CO1]** 3+3 = 6

   b) Give an account for ionic bonding and covalent bonding. **[CO1]** 5

   c) The net potential energy between two adjacent ions, E_N, is represented by the equation: $E_N = -\frac{A}{r} + \frac{B}{r^n}$; where A, B and n are constants and r is the distance between two adjacent ions. Calculate the bonding energy E_o in terms of parameters A, B and n. **[CO1]** 5

   c) What is meant by ionic character of a solid and how it represented? **[CO1]** 4

[Turn over

5. (a) What should be the energy of the quantum state which has 19 for the sum of the squares of the quantum numbers n_x, n_y *and* n_z? What is the degeneracy of this state? Assume the solid to be of dimension 10 mm x 10 mm x 10 mm. **[CO3]** 4+3 = 7

(b) If a small piece of metal contains 120 free electrons then how these electrons would occupy different energy levels and what will be the energy of the electrons at the highest energy level? **[CO3]** 3

c) State the assumptions considered in developing the 'free electron theory' of metals. Derive the kinetic energy of free electrons as a function of their wave number after deriving all the necessary relationships. **[CO3]** 3+7 = 10

OR

6. a) On the basis of Drude's Model derive the necessary relationship to find the thermal conductivity of metals. **[CO3]** 8

b) Calculate the drift velocity of electrons in copper and current density in wire of diameter 0.16 cm which carries a steady current of 10 A. Given $n = 8.46 \times 10^{28}$ m^{-3}. **[CO3]** 5

c) A conducting rod contains 8.5×10^{28} electrons/m^3. Calculate its resistivity at room temperature and also the mobility of electrons if the collision time for electron scattering is 2×10^{-14} sec. **[CO3]** 7

7. a) What is the fundamental difference between 'classical mechanics" and "wave mechanics?" **[CO3]** 2

b) What is the difference between a "mechanical wave" and wave connected with "wave mechanics"? **[CO3]** 2

c) What do you understand by "wave function, ψ?" What is the necessity of $|\psi^2|$ in wave mechanics? **[CO3]** 4

d) Derive the relationship for time independent form of Schrodinger's wave equation. **[CO3]** 7

e) A particle limited to the X-axis has the wave function $\psi = ax$ between $x = 0$ and $x = 1$; $\psi = 0$ elsewhere. Find the probability that the particle can be found between $x = 0.45$ and $x = 0.55$. **[CO3]** 5

OR

8. a) Show that the energy of a confined particle in a certain region in space is quantized. What general conclusions are drawn about the energy of such confined particle? **[CO3]** 6 +4 = 10

b) Find the probability that a particle trapped in a box of width "L" can be found between 0.45 L and 0.55L for the first and first excited states. Also show your result by suitable plot and plotting and make comment. **[CO3]** 5+5 = 8

9. a) Discuss the origin of the discontinuous E-K plot in terms of band theory of metals. **[CO4]** 8

b) What is the First and Second Brillouin zone. **[CO4]** 4

c) Define Fermi Level and Fermi energy. Use the Fermi distribution function to obtain the value of F(E) for $E - E_F = 0.01$ eV at 200K. **[CO4]** 4+4 = 8

OR

10. a) Discuss the origin of classifying different materials in terms of their conductivity. **[CO4]** 10

b) Discuss the origin of magnetism and also discuss the classification of different materials classified according to their magnetic susceptibility. **[CO5]** 10