INDIAN INSTITUTE OF TECHNOLOGY

Sub. Name : Materials Engineering | **Sub. No. MT-30001**

Time : 2 hrs. | Full Marks : 60 | No. of Students : 125

Midterm Examination | Autumn Semester, 2010

Instructions:

- Attempt **ANY FOUR (4).**
- Show your working and reasoning carefully for credit. Draw schematic diagrams wherever necessary.
- Points for each question are written below.
- Closed books, closed notes, closed laptop and cell phones. A calculator is allowed only.

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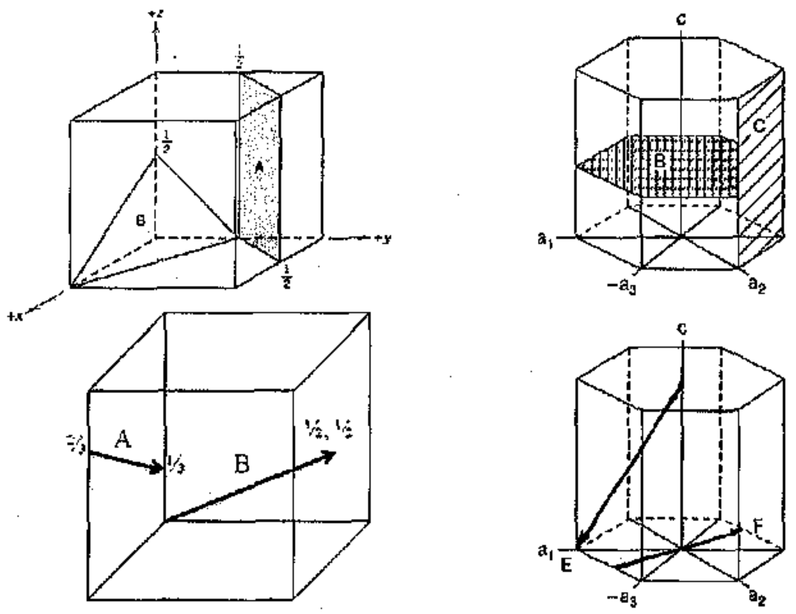
1. (a) Determine the Miller indices of the following planes and directions:



(b) What is the fractional volume change in iron as it transforms from γ (a = 0.365 nm) to δ (a = 0.293) at 1394°C? What is the volume change if Fe atoms of fixed radius pack as hard spheres?
(c) Atoms of a body-centered tetragonal metal are arranged in a square array on the (001) plane with a lattice constant of 0.460 nm. On the (100) and (010) planes, atoms are arranged in a rectangular array with lattice constants of 0.460 and 0.495 nm. Sketch the atomic positions on the (110) plane and indicate the dimensions.

8 + 4 + 3 = **15**

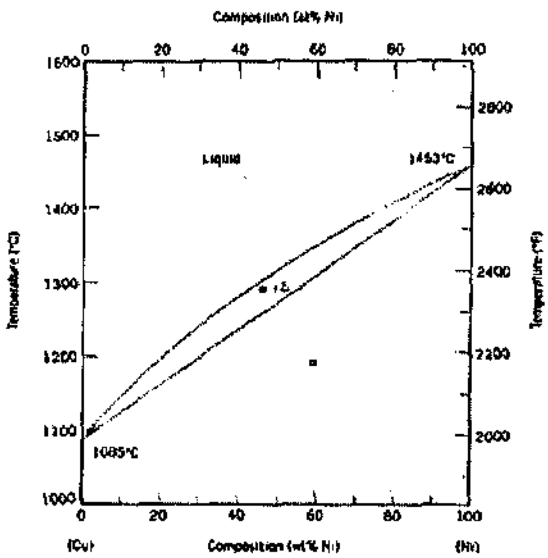
2. (a) Why polymers show high degree of deformation although they have primary covalent bonding?
(b) Differentiate between resilience and toughness.
(c) What is slip system? Why deformation in FCC metals is greater than BCC metals although BCC has more slip system than FCC?
(d) Describe the microstructural features developed in a casting process.
(e) Compute the number of atoms/m^3 in pure Fe. Density of Fe = 7.8 g/cm^3; A(Fe) = 55.85; Z(Fe) = 26; Crystal Structure = BCC

(f) Considering both temperature and pressure to be variables, what is the largest number of phases that can coexist at equilibrium in a binary alloy?

(g) Briefly explain why a proeutectoid phase (ferrite or cementite) forms along austenite grain boundaries.

$2 + 2 + 3 + 2 + 2 + 2 + 2 = \mathbf{15}$

3. (a) Use the following diagram to answer the questions below: A copper-nickel alloy of composition 70 wt% Cu is slowly cooled from a temperature of 1300°C.
   - (i) At what temperature does the first phase change will occur?
   - (ii) What are the compositions of these liquid and solid phases?
   - (iii) At what temperature does complete solidification of the alloy occur?
   - (iv) What is the composition of the last liquid remaining prior to complete solidification?



(b) Cite and identify the following position(s) of defect(s) with a vertical dashed line:

(i) ....ABABBBABA....

(ii) .....ABABABBABAABABAB.....

(iii) .....ABCABABCABC.....

(c) In the table (next page), atomic radius, crystal structure, electronegativity, and the most common valence are tabulated for several elements; for those that are nonmetals, only atomic radii are indicated. Which of these elements would you expect to form the following with nickel:

(i) a substitutional solid solution having complete solubility?

(ii) a substitutional solid solution of incomplete solubility?

(iii) an interstitial solid solution?

Justify your answer.

Element	*Atomic Radius (nm)*	*Crystal Structure*	*Electronegativity*	*Valence*
Ni	0.1246	FCC	1.8	+2
C	0.071			
O	0.060			
Ag	0.1445	FCC	1.9	+1
Al	0.1431	FCC	1.5	+3
Cr	0.1249	BCC	1.6	+3
Fe	0.1241	BCC	1.8	+2
Cu	0.1278	FCC	1.9	+2
Pd	0.1376	FCC	2.2	+2
Zn	0.1332	HCP	1.6	+2

(d) For an FCC single crystal, would you expect the surface energy for a (100) plane to be greater or less than that for a (111) plane? Explain.

$4 + 3 + 6 + 2 = \mathbf{15}$

4. (a) Consider a single crystal of nickel oriented such that a tensile stress is applied along a [001] direction. If slip occurs on a (111) plane and in a [101] direction, and is initiated at an applied tensile stress of 13.9 MPa, compute the critical resolved shear stress.

Given: An angle between directions, θ can be expressed as

$$\theta = cos^{-1}\left[\frac{u_1u_2 + v_1v_2 + w_1w_2}{\sqrt{(u_1^2 + v_1^2 + w_1^2)(u_2^2 + v_2^2 + w_2^2)}}\right]$$

[Hint: For cubic crystals, planes and directions having the same indices are perpendicular to one another.]

(b) If the true-stress–true-strain curve is given by $\sigma = 1400\varepsilon^{0.33}$, where stress is in MPa, determine the ultimate tensile strength of the material.

[Given: Uniform elongation at maximum load is ε = n; engineering stress, s = σ/(e + 1); true strain, ε = ln (e + 1) where e = engineering strain]

(c) How can a pure metal be strengthened without changing the composition? Why cold working of tin (melting point 232°C) is not possible at room temperature?

(c) In what way recrystallization is different from recovery? How do you distinguish between hot and cold working?

5 + 4 + 4 + 2 = **15**

5. (a) The density of BCC Chromium is 7.19 g/cc. Find the lattice parameter if the atomic weight of the Cr is 54.01. [Given: 1 amu = 1.66×10^{-24} g]

(b) Determine the magnitude of the Schmid factor for an FCC single crystal oriented with its [120] direction parallel to the loading axis.

(c) Why do new phases usually nucleate in the grain boundaries of the prior unstable grains during solid-state transformations? What is significant about the magnitudes of the critical radii and the numbers of stable nuclei? Suggest microstructural feature of a fast cooled liquid.

(d) For the solidification of nickel, calculate the critical radius r^* and the activation free energy ΔG^* if nucleation is homogeneous. Values for the latent heat of fusion and surface free energy are -2.53×10^9 J/m^3 and 0.255 J/m^2, respectively. Degree of supercooling value for homogeneous nucleation and the melting point of Ni metal is 319 °C and 1450 °C, respectively.

Given:

$$r^* = \frac{-2\gamma T_m}{\Delta H_s(T_m - T)} = \frac{-2\gamma}{\Delta G_v} \qquad \Delta G^* = \frac{16\pi\gamma^3}{3(\Delta G_v)^2}$$

4 + 3 + 4 + 4 = **15**