**Birla Institute of Technology and Science, Pilani**
**Second Semester, 2017-18**
**CHE F243-Materials Science and Engineering**

**Mid Semester (Closed Book)** **8th March, 2018 (2-3:30PM)**
**Max Time: 90 min** **Total Max Marks:75**

- Only the equations shown in your text book could be used directly. Other necessary equations must be derived
- Box the final and intermediate answers. Mention unit.
- Don't skip any mathematical steps-otherwise you will lose marks

**Q1:**

a) Iron has a BCC crystal structure, an atomic radius of 0.124 nm, and an atomic weight of 55.85 g/mol. Compute its theoretical density in gm/cc. **[4]**

b) Zirconium has an HCP crystal structure, atomic weight $A_{Zr}$ = 91.22 g/mol, and a density of 6.51 g/cm$^3$.

i. What is the volume of its unit cell in cubic meters? **[3]**

ii. If the c/a ratio is 1.593, derive the necessary relationship (start from the basic structure of HCP unit cell and show each step of the calculation with a proper diagram which you will use for the calculation) connecting volume of HCP with 'c' and 'a' and compute the values of 'c' and 'a' in nm only. **[7]**

c) Three different crystallographic planes for a unit cell of some hypothetical metal are shown below (Fig. A). The circles represent atoms.

i. Draw the planes in three different unit cells, and show the lattice parameters in one of them. Clarity of the drawing is a must. **[1 x 3]**

ii. To what crystal system does the unit cell belong? What would this crystal structure be called? **[1]**

iii. If the density of this metal is 8.95 g/cm$^3$, determine its atomic weight. **[2]**

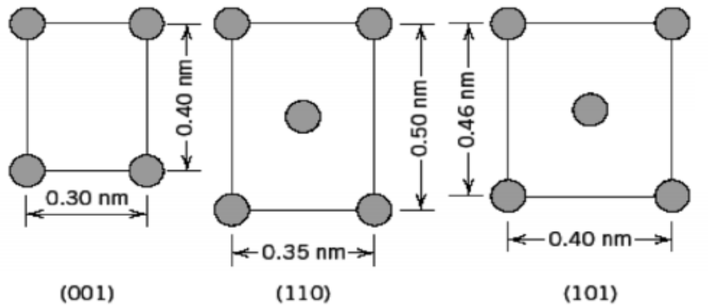



Fig. A

**Q2: Drawing figures not necessary, but must show the steps.**

a) Determine the <u>Miller indices</u> for the directions (A, B, C, and D) shown in the following cubic unit cell (Fig. 1). The origin cannot be changed. Label your answers (A, B, C, and D) clearly. **[4 x1]**

b) Determine the Miller indices for the planes (A and B) shown in the following unit cell (Fig.2). The origin cannot be changed. Label your answers (A and B) clearly. **[2x1]**

c) Determine the <u>Miller-Bravais</u> indices for the planes (A, B, and C) shown in the hexagonal unit cells below (Fig.3). The origin cannot be changed. Label your answers (A, B, and C) clearly. Explain the method you have followed. **[2x3]**

Fig 1

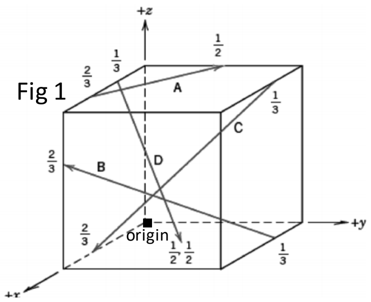
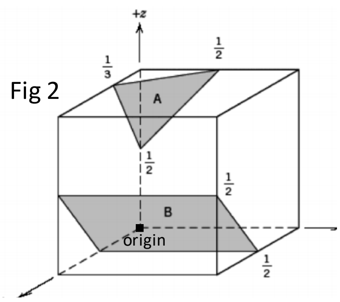



Fig 2



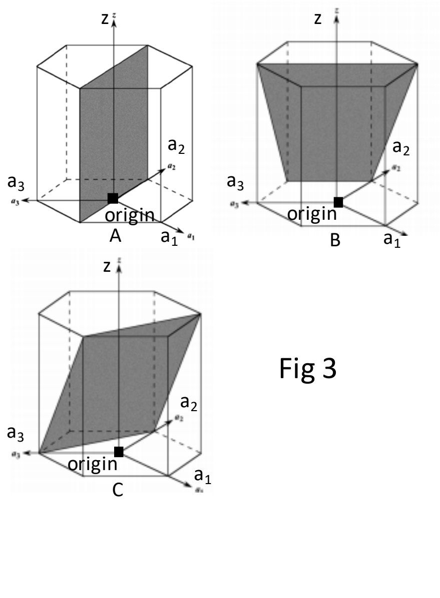




Fig 3

**Q3:** Determine the expected diffraction angles correspond to the first five reflections (first-order) for polycrystalline FCC platinum crystal when monochromatic radiation of wavelength 0.1542 nm is used and atomic radius of Pt is 0.139 nm. Mention all necessary variables (data), assumptions, and equations at the beginning of the answer. <u>Show the final and all intermediate results in a tabular form</u>. Explain the method clearly. **[5 x 2+5]**

**Q4:**

a) Derive planar density expressions for (100) and (111) planes of an FCC unit cell in terms of the atomic radius R. Show each step of the calculation with a proper diagram which you will use for the calculation. Which FCC plane [(100) or (111)] has higher surface energy (SE)? Define SE and explain your answer.
**[2+2+2]**

b) A sheet of BCC iron 1 mm thick was exposed to a carburizing gas atmosphere on one side and a decarburizing atmosphere on the other side at 725° C. After having reached steady state, the iron was quickly cooled to room temperature. The carbon concentrations at the two surfaces of the sheet were determined to be 0.012 and 0.0075 wt%. Compute the diffusion coefficient if the diffusion flux is $1.4 \times 10^{-8}$ kg/m$^2$-s. The density of carbon = 2.25 gm/cm$^3$; density of iron = 7.87 gm/cm$^3$ **[7]**

**Q5:**

a) Write the relationships between true and engineering stress and strain and derive the respective equations. Mention necessary assumption(s) and explain notations clearly. **[2+2]**

b) Find the toughness (in terms of energy/unit volume) for a metal that experiences both elastic and plastic deformation. Assume that the modulus of elasticity is 172 GPa ($25 \times 10^6$ psi), and that elastic deformation terminates at a strain of 0.01. For plastic deformation, assume that the values for K (strength index) and n (strain hardening exponent) are 6900 MPa ($1 \times 10^6$ psi) and 0.30, respectively. Furthermore, plastic deformation occurs between true strain values of 0.01 and 0.75, at which point fracture occurs. **[5]**

c) Consider that a single crystal of aluminum is oriented for a tensile test such that its slip plane normal makes an angle of 28.1° with the tensile axis. Three possible slip directions make angles of 62.4°, 72.0°, and 81.1° with the same tensile axis. Answer the following questions.

i. Which of these three slip directions is most favored? Explain with proper logic/calculation. **[3]**

ii. If plastic deformation begins at a tensile stress of 1.95 MPa (280 psi), determine the critical resolved shear stress for single crystal of aluminum. **[3]**

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