BITS PILANI, DUBAI CAMPUS
DUBAI INTERNATIONAL ACADEMIC CITY, DUBAI, UAE

Second Semester 2010-2011

COMPREHENSIVE EXAMINATION (Closed book)

Year : II	Date : 1.06.2011	
Course No. : ES C242	Course Title : Structure and Properties of Materials	
Duration : 3 hours.	Marks: 120	Weightage : 40%

Note: (i) Answer all the questions.
(ii) Answer Part A in blue, Part B in green and Part C in brown answer books.
(iii) Take Avogadro number = 6.023×10^{23} atoms/mol.

Part – A

1. A hypothetical AX type of ceramic material is known to have a density of 2.10 g/cm^3 and a unit cell of cubic symmetry with a cell edge length of 0.57 nm. The atomic weights of the A and X elements are 28.5 and 30.0 g/mol, respectively. On the basis of this information, determine which crystal structure is/are possible for this material: Sodium Chloride, Cesium Chloride or Zinc Blende. **(10 M)**

2. Make a plot of bonding energy versus melting temperature for the metals listed below. Using this plot, approximate the bonding energy for copper, which has a melting temperature of 1084° C.

	Bonding Energy (e V / atom)	**Melting temperature (° C)**
Hg	0.7	-39
Al	3.4	660
Fe	4.2	1538
W	8.8	3410

(10 M)

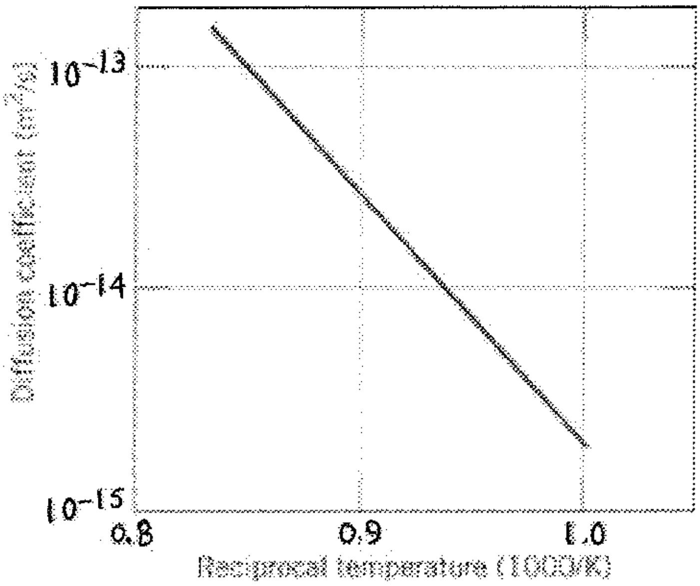
3. a) Calculate the density of atoms along BCC [110] directions in terms of the atomic radius R and hence calculate the density of tungsten (radius of tungsten atom = 0.137nm).
(b) Sketch the $(3\bar{1}2)$ plane within a cubic unit cell. **(10 M)**

Part – B

4. Silver and palladium both have the FCC crystal structure, and Pd forms a substitutional solid solution for all concentrations at room temperature. Compute the unit cell edge length for a 75 wt% Ag–25 wt% Pd alloy. The room-temperature density of Pd is 12.02 g/cm^3, and its atomic weight and atomic radius are 106.4 g/mol and 0.138 nm, respectively. The room-temperature density and atomic weight of Ag are 10.47 g/cm^3 and 107.9 g/mol respectively. **(10 M)**

5. Below is shown a plot of the logarithm (to the base 10) of the diffusion coefficient versus reciprocal of the absolute temperature, for the diffusion of gold in silver. Determine values for the activation energy and preexponential. R = 8.31 J/mol-K

(10 M)



6. Two previously undeformed cylindrical specimens of an alloy are to be strain hardened by reducing their cross-sectional areas (while maintaining their circular cross sections). For one specimen, the initial and deformed radii are 15 mm and 12 mm, respectively. The second specimen, with an initial radius of 11 mm, must have the same deformed hardness as the first specimen; compute the second specimen's radius after deformation. **(10 M)**

7. An electrochemical cell is composed of pure copper and pure cadmium electrodes immersed in solutions of their respective divalent ions. Half potentials of copper and cadmium are +0.340 V and -0.403 V respectively. For a 6.5×10^{-2}M concentration of Cd^{2+}, the cadmium electrode is oxidized yielding a potential of 0.775 V. Calculate the concentration of Cu^{2+} ions at a temperature of 45^0C. **(10 M)**

8. Below, molecular weight data for a polytetrafluoroethelene material are tabulated. Compute(a) the number average molecular weight (b) the weight average molecular weight and (c) the degree of polymerization. **(10 M)**

Molecular weight range (gmol^{-1})	x_i	w_i
10000-20000	0.01	0.03
20000-30000	0.09	0.04
30000-40000	0.15	0.11
40000-50000	0.25	0.23
50000-60000	0.22	0.24
60000-70000	0.14	0.18
70000-80000	0.08	0.12
80000-90000	0.04	0.07

9. A wire whose diameter is 2 mm must carry a 20 A current. The maximum power dissipation along the wire is 4 watts per meter. Calculate the minimum allowable conductivity of the wire in (ohm meter)$^{-1}$ for this application. **(10 M)**

Part – C

10. A cylindrical specimen of a brass alloy 10.0 mm in diameter and 120 mm long is pulled in tension with a force of 11,750 N; the force is subsequently released.

   (a) Compute the final length of the specimen at this time. The tensile stress-strain behavior for this alloy is shown in the figure below.

   (b) Compute the final specimen length when the load is increased to 23,500 N and then released.

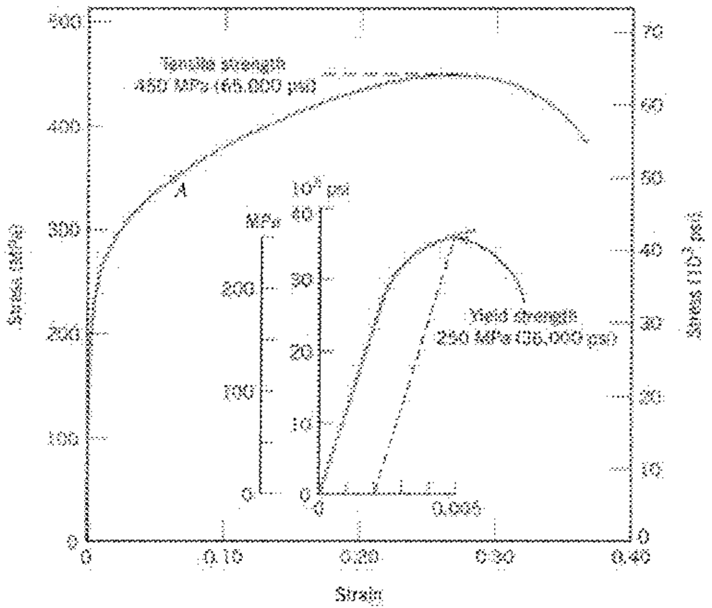


Figure 6.12 The stress-strain behavior for the brass specimen discussed in Example Problem 6.3. **(10 M)**

11. (a) Using the isothermal transformation diagram attached, determine the final microstructure (just the microstructure not percentage). In each case assume that the specimen begins at 920°C

   i) Rapidly cool to 250°C, hold for 10^3 s, then quench to room temperature

   ii) Rapidly cool to 775°C, hold for 500 s, then quench to room temperature.

   iii) Rapidly cool to 400°C, hold for 500 s, then quench to room temperature.

   iv) Rapidly cool to 700°C, hold at this temperature for 10^5 s, then quench to room temperature.

   v) Rapidly cool to 650°C, hold at this temperature for 3 s, rapidly cool to 400°C, hold for 25 s, then quench to room temperature

vi) Rapidly cool to 350°C, hold for 300 s then quench to room temperature.

vii) Rapidly cool to 675°C, hold for 7 s, then quench to room temperature

(b) On the attached diagram sketch and label time-temperature paths to produce the following microstructure.

i) 50% fine pearlite and 50% bainite

ii) 100% martensite

iii) 100% tempered martensite **(10 M)**

12. Consider 2.0 kg of a 99.6 wt% Fe-0.4 wt% C alloy that is cooled to a temperature just below the eutectoid. Using the following phase diagram calculate:

(a) How many kilograms of proeutectoid ferrite form?

(b) How many kilograms of eutectoid ferrite form?

(c) How many kilograms of cementite form? **(10 M)**

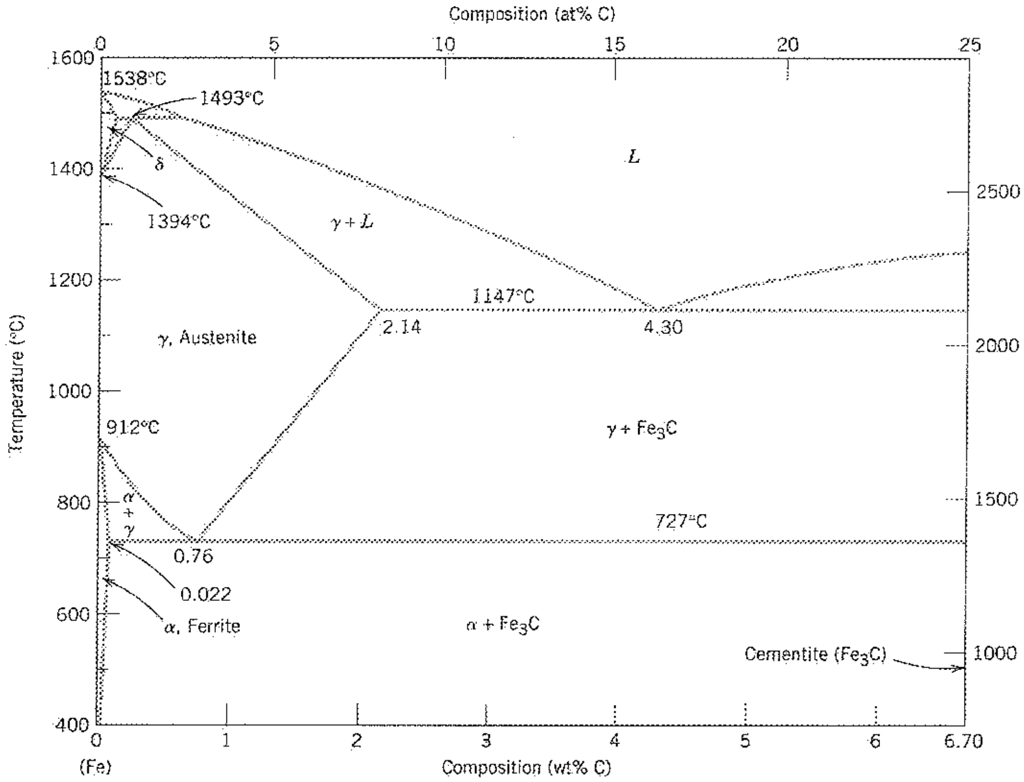
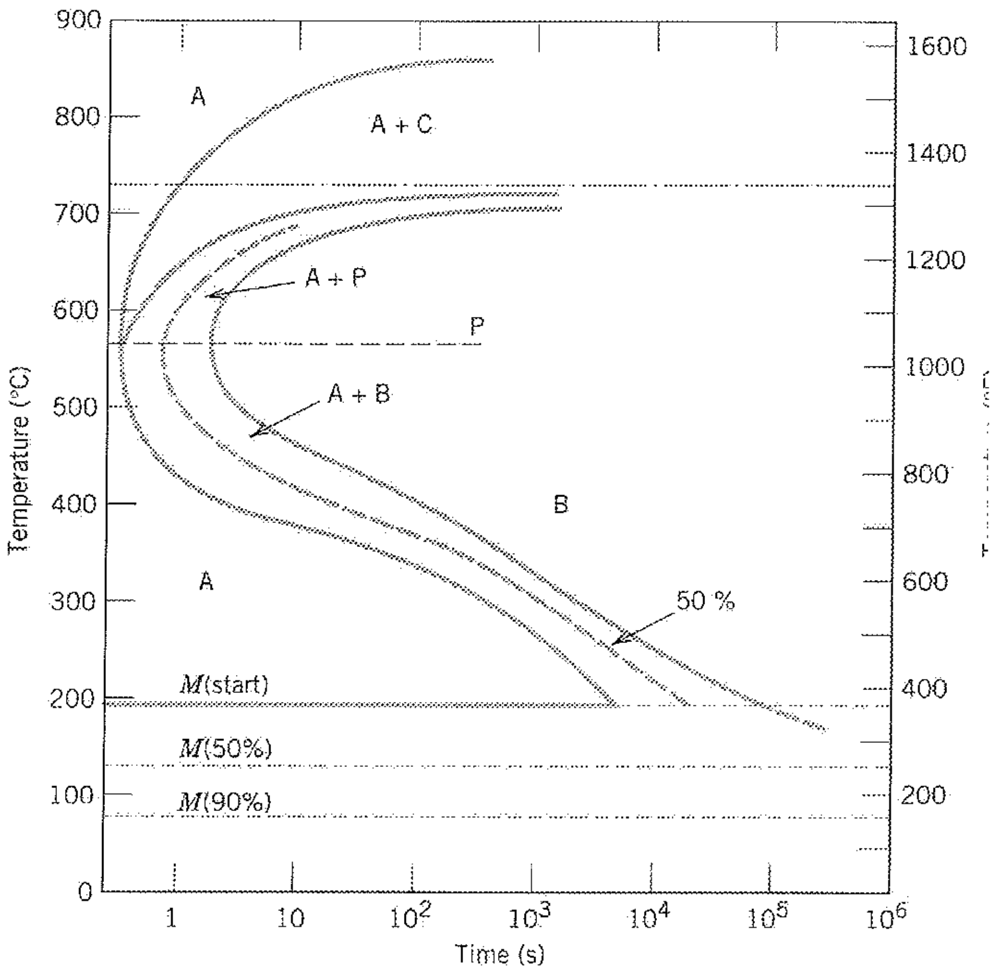


Figure 9.21 The iron–iron carbide phase diagram. [Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 1, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

Use the diagram given below for answering question number 11 and attach it with **Part C** of the Answer booklet

FIGURE 10.28 Isothermal transformation diagram for a 1.13 wt% C iron–carbon alloy: A, austenite; B, bainite; C, proeutectoid cementite; M, martensite; P, pearlite. [Adapted from H. Boyer (Editor), *Atlas of Isothermal Transformation and Cooling Transformation Diagrams*, American Society for Metals, 1977, p. 33.]



BITS PILANI, DUBAI CAMPUS

Dubai International Academic City, Dubai, U.A.E

II Year II Semester 2010-2011

Test No.2 (Open Book)

Course No. ES C242 **Course Title:** Structure and properties of materials

Date: 10-04-2011 **Max. Marks:** 60

Weightage: 20% **Duration:** 50 min

Notes:

- *Answer all the questions*
- *Draw neat sketches wherever necessary*
- *Make suitable assumptions if required and clearly state them*
- *Consider all the constants value as given in the text book*

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1. Calculate the activation energy for vacancy formation in aluminum, given that the equilibrium number of vacancies at 500°C (773 K) is 7.57 × 1023 m^{-3}. The atomic weight and density (at 500°C) for aluminum are, respectively, 26.98 g/mol and 2.62 g/cm^3. **[15 marks]**

2. Molybdenum forms a substitutional solid solution with tungsten. Compute the weight percent of molybdenum that must be added to tungsten to yield an alloy that contains 1.0×10^{22} Mo atoms per cubic centimeter. The densities of pure Mo and W are 10.22 g/cm^3 and 19.30 g/cm^3, respectively.

[15 marks]

3. At 950°C, 0.8% carbon steel is getting decarburized for duration of 4hr in an atmosphere equivalent to 0% carbon at the surface of the steel. Determine the minimum depth upto which the specimen has to be machined if the carbon content at the surface after machining should not be below 0.6%. Assume that the preexponential and activation energy for the diffusion coefficient are 0.7×10^{-4} m^2/s and 157 KJ/mol, respectively.

[15 marks]

4. (a) A single crystal of silver oriented such that a tensile stress is applied along a [001] direction. If slip occurs on (111) plane and in a [$\bar{1}$01] direction, and is initiated at an applied stress of 1.1 MPa, compute the critical resolved shear stress. **[7 marks]**

(b) The yield strength of mild steel with an average grain size of 0.05 mm is 20,000 psi. The yield stress of the same steel with a grain size of 0.007 mm is 40,000 psi. What will be the average grain size of the same steel with a yield stress of 30,000 psi. Assume that the changes in the observed yield stress are due to changes in the grain size alone. (1000 psi = 6.895 MPa) **[8 marks]**

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BITS, Pilani –Dubai

Dubai International Academic City, Dubai, U.A.E

II Year II Semester 2010-2011

Test No.1 (Closed Book)

Course No. ES C242 **Course Title:** Structure and properties of materials

Date: 20-02-2011 **Max.Marks:** 75

Weightage: 25% **Duration:** 50 min

Notes:

- *Answer all the questions*
- *Draw neat sketches wherever necessary*
- *Make suitable assumptions if required and clearly state them*
- Assume **N_A=6.023 X 10^{23} atoms/mole**

1. For a Na^+ - Cl^- ion pair, attractive and repulsive energies E_A and E_R respectively depend on the distance between the ions r according to

   $E_A = -1.436/r$

   $E_R = 7.32 \times 10^{-6}/r^8$

   For these expressions, energies are expressed in electron volts per Na^+ -Cl^- pair, and r is the distance in nanometers. The net energy E_N is just the sum of the two expressions above.

   (a) Superimpose on a single plot E_N, E_R, E_A versus r up to 1.0 nm.

   (b) On the basis of this plot, determine (i) the equilibrium spacing r_0 between the Na^+ and Cl^- ions and (ii) magnitude of the bonding energy E_0 between the two ions.

   (c) Mathematically determine the r_0 and E_0 values. **[20 marks]**

2. Compute the percentage ionic character of interatomic bond of H—Cl and H—Br. Given electronegativity of chlorine is 3.0, bromine is 2.8 and hydrogen is 2.1. **[15 marks]**

3. (a) Calculate the theoretical volume change accompanying a polymorphic transformation in a pure metal from the FCC to BCC crystal structure. Assume the hard-sphere model and that there is no change in atomic volume before and after the transformation. **[10 marks]**

   (b) The unit cell for Uranium has orthorhombic symmetry, with 'a', 'b' and 'c' lattice parameters of 0.286nm, 0.587 nm and 0.495 nm respectively. If its density, atomic weight and atomic radius are 19.05 gcc^{-1}, 238.03$gmol^{-1}$ and 0.1385 nm respectively, compute its atomic packing factor. **[10 marks]**

4. (a) Calculate the radius of a Molybdenum atom, given that Molybdenum has a BCC crystal structure, a density of 10.22 g/cm^3, and an atomic weight of 95.94 g/mol. **[10 marks]**

   (b) The lattice parameters, a, b and c of a unit cell are 0.2 nm, 0.3 nm and 0.3 nm. The interaxial angles are 90°. Find the crystal system of the unit cell and draw the body centered structure of the unit cell. **[10 marks]**

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Qui3-2

BITS PILANI, DUBAI CAMPUS

SECOND SEMESTER 2010- 2011

Version **A**

Course Code: ES C242 Second **YEAR** Date: 26.4.2011

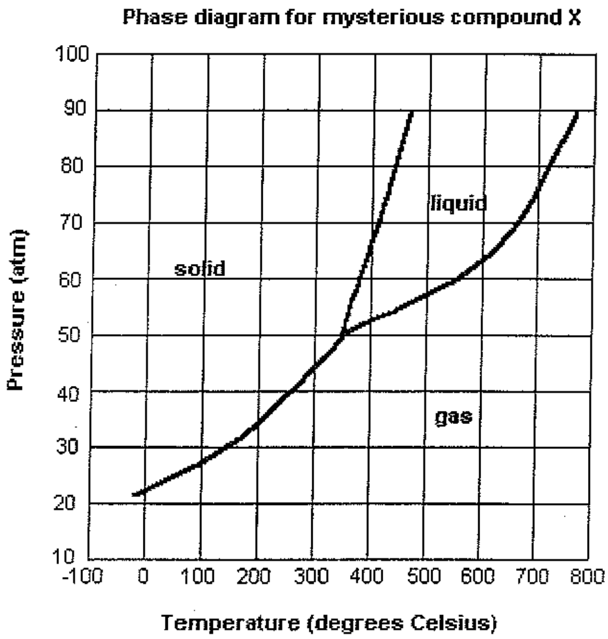
Course Title: Structure and Properties of Materials Max Marks: 21

Duration: 20 minutes Weightage: 7%

Name:	**ID No:**	**Sec / Prog:** .....

1. From the following phase diagrams answer the questions given below.
   a) What is the critical temperature of compound X?
   b) At what temperature and pressure will all three phases coexist?
   c) If I have a bottle of compound X at a pressure of 45 atm and temperature of 100^0 C, what will happen if I raise the temperature to 400^0 C?

   (3 Marks)



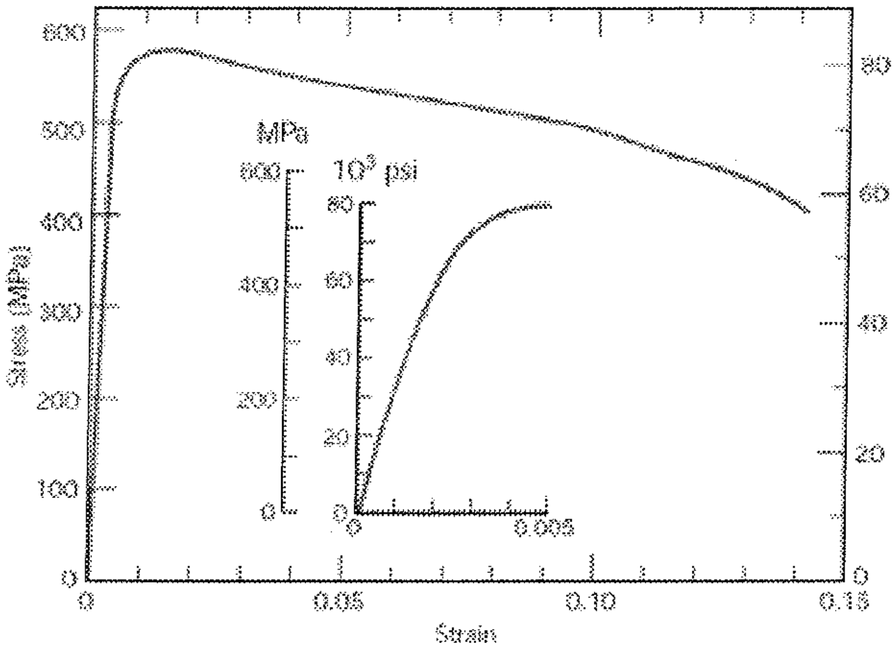
a)

b)

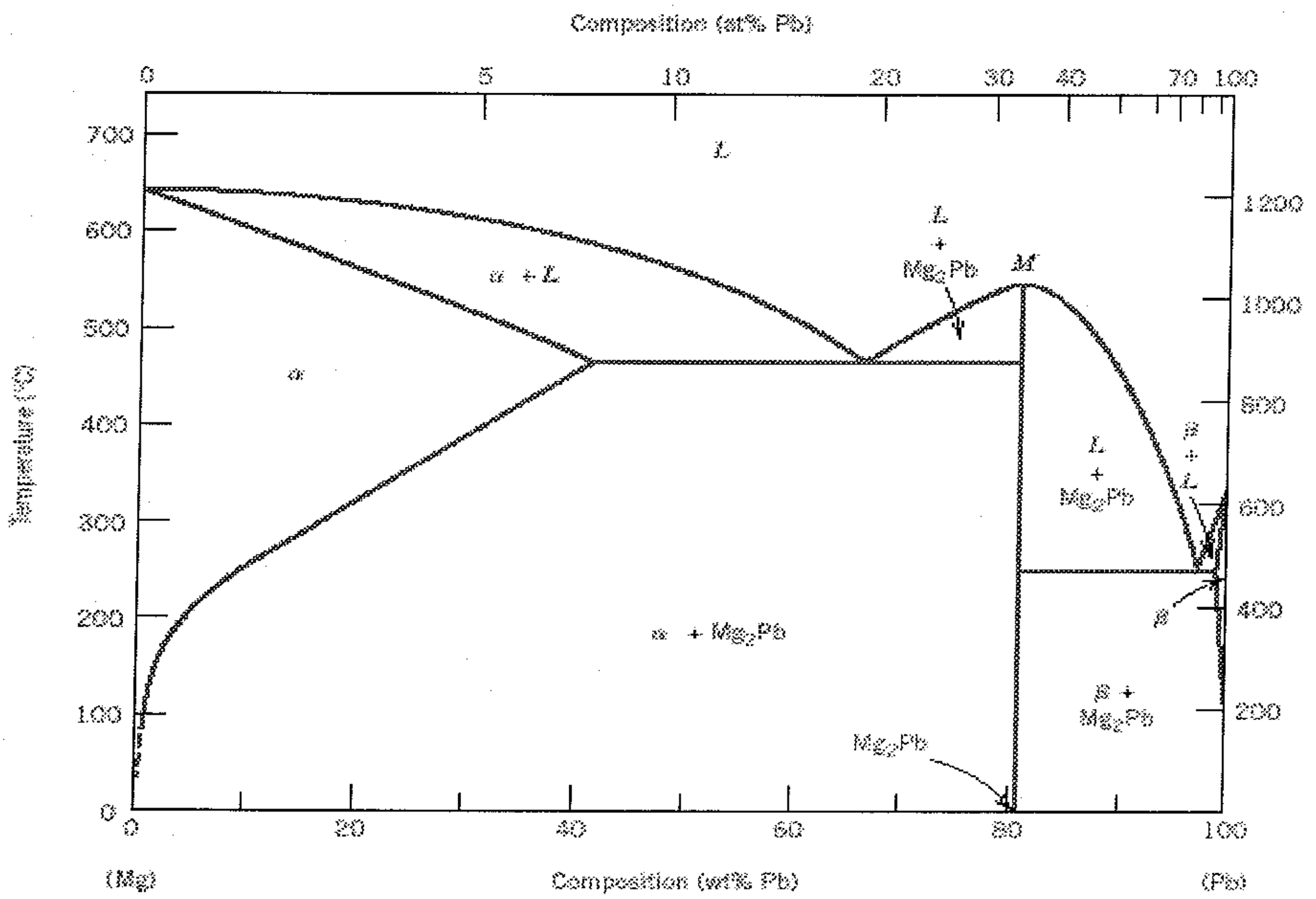
c)

2. Derive the equation $\sigma_T = \sigma\,(1 + \varepsilon)$ assuming there is no volume change during deformation. (4 Marks)

3. Consider a cylindrical specimen of a certain alloy (Figure given below) 10 mm in diameter and 75 mm long is pulled in tension. Determine its elongation when a load of 20,000 N (4,500 lbf) is applied. Also find the total strain when a load of 40,000N is applied. (5 Marks)



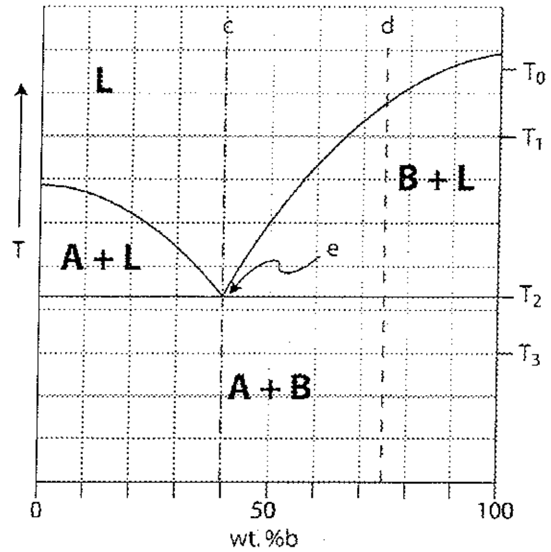
4. A 45 wt% Pb-55 wt% Mg alloy is rapidly quenched to room temperature from an elevated temperature in such a way that the high temperature microstructure is preserved. This microstructure is found to consist of the α phase and Mg_2Pb, having respective mass fractions of 0.65 and 0.35. Determine the approximate temperature from which the alloy was quenched. (6 Marks)



PTO

5. Using the phase rule, determine the degrees of freedom:
   a. at point e
   b. within the field A + B
   c. within the field L

(3 Marks)



9W321

BITS PILANI, DUBAI CAMPUS
SECOND SEMESTER 2010- 2011

Course Code: ES C242 II YEAR Date: 13.3.2011 Course

Title: Structure and Properties of Materials Max Marks: 24

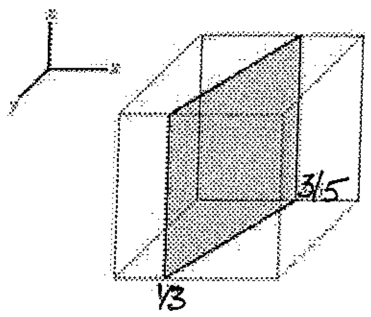
Duration: 20 minutes Weightage: 8%

Name: .... **ID No:** .... **Sec / Prog:** .....

1. a) Draw and derive density expressions for the BCC (110) and FCC [100] in terms of the atomic radius R. [4 Marks]

   b) Compute the BCC (111) planar density for molybdenum which has an atomic radius of 0.136 nm. [4 Marks]

2. a) Draw the plane whose Miller indices are $(12\bar{1})$. [2 Marks]
b) Find the miller indices for the plane shown below. [2 Marks]



3. a) Determine the ceramic structure for which the coordination number of 8.

[2 Marks]

b) Demonstrate that the minimum cation to anion radius ratio for a coordination number of 8 is 0.732.

[4 Marks]

4. a) Calculate the density for MgO. Given $A_{Mg} = 24.31$ g/mol, $A_O = 16$ g/mol. The radius of Magnesium and Oxygen are 0.072 nm and 0.140 nm respectively.

[4 Marks]

b) Zinc blende crystal structure is one that may be generated from close-packed planes of anions. Will the cations fill tetrahedral or octahedral positions? Why?

[2 Marks]