BITS, PILANI - DUBAI

DUBAI INTERNATIONAL ACADEMIC CITY, DUBAI, UAE

Second Semester 2009-2010

COMPREHENSIVE EXAMINATION (Closed book)

Year	: II	Date	:24.05.2010
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

Q1. The potential energy of a system of two atoms is given by the relation $U = -\frac{A}{r^2} + \frac{B}{r^{10}}$. A stable molecule is formed with the release of 8 eV when the inter atomic distance is 2.8 Å. Find the values of A and B. **(10 M)**

Q2. (a) Calculate planar density of atoms in the (111) plane of a BCC Tungsten. Take atomic radius of Tungsten as 0.137 nm. **(5 M)**

(b) Draw a tetragonal unit cell and within that indicate the locations of $\frac{1}{2}\frac{1}{4}\frac{1}{2}$ point coordinates. **(5 M)**

Q3. (a) Prove that the minimum cation to anion ratio for a coordination number of 8 is 0.732. **(5 M)**

(b) The unit cell of 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 g/cm^3, 238.03 g/mol and 0.1385 nm respectively, compute the atomic packing factor. **(5 M)**

Q4. Copper and Platinum both have the FCC crystal structure, and Copper forms a substitutional solid solution for concentrations up to approximately 6 wt% Cu at room temperature. Compute the unit cell edge length for 95 wt% Pt – 5 wt% Cu. Take ρ_{Cu} = 8.94 g/cm^3 and ρ_{Pt} = 21.45 g/cm^3. Take A_{Cu} = 63.55 g/mol and A_{Pt} = 195.08 g/mol. **(10 M)**

Q5. Consider an alloy that initially has a uniform carbon concentration of 0.25 wt% and is to be treated at 950°C. If the concentration of carbon at the surface is suddenly brought to and maintained at 1.20 wt%, how long will it take to achieve a carbon content of 0.80 wt% at a position 0.5mm below the surface? The diffusion coefficient for carbon in iron at this temperature is 1.6×10^{-11} m^2/s. **(10 M)**

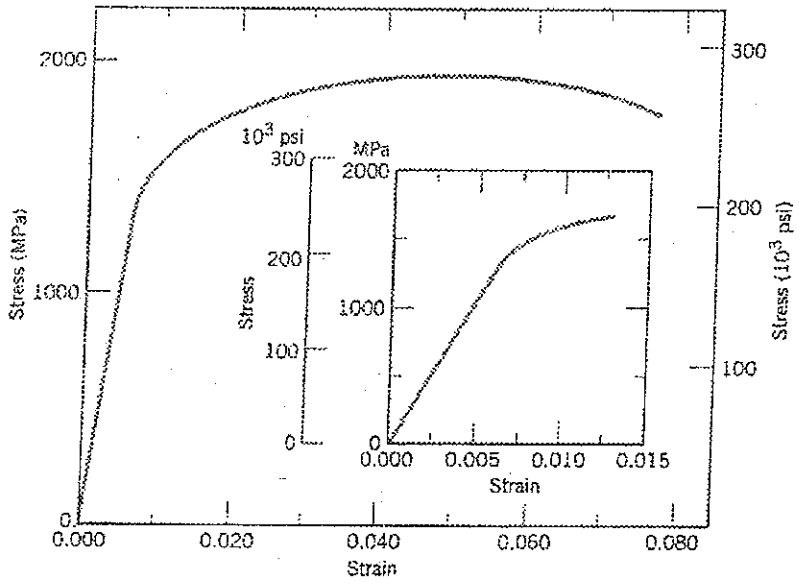
Z	erf (Z)	Z	erf (Z)
0.30	0.3286	0.45	0.4755
0.35	0.3794	0.50	0.5205
0.40	0.4284	0.55	0.5633

Q6. A steel alloy specimen having a rectangular cross section of dimensions 19 mm x 3.2 mm has a stress-strain behavior shown in Fig. Q6. If this specimen is subjected to a tensile force of 110000 N then,

(a) Determine the elastic and plastic strain values.

(b) If its original length is 610 mm what will be its final length after the load in part (a) is applied and then released? Take E_{steel} = 207 GPa **(10 M)**

Fig. Q6



Part - B

Q7. Consider a single crystal of silver oriented such that a tensile stress is applied along a [001] direction. If slip occurs on a (111) plane and in a $[\bar{1}01]$ direction, and is initiated at an applied tensile stress of 1.1 MPa, calculate the critical resolved shear stress. **(10 M)**

Q8. Given in Fig. Q8 is the phase diagram of copper-nickel. For an alloy of composition 35 wt% Ni – 65 wt% Cu, cite the following at A, B, C, D and E (Refer Fig. Q8):

(a) Phases

(b) Phase compositions in terms of mass fractions

(c) Draw the equilibrium microstructures **(10 M)**

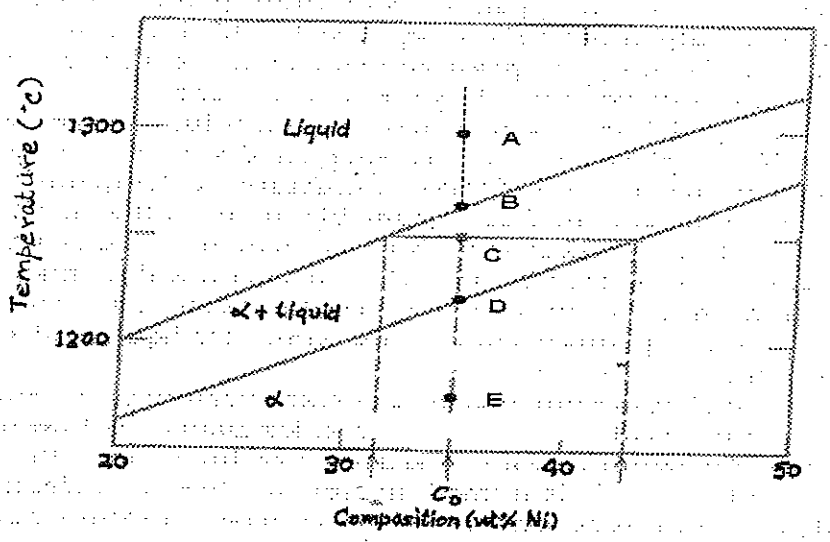


Fig. Q8

Q9. Using the TTT diagram for an iron-carbon alloy of eutectoid composition (Fig. Q9), specify the final microstructure, in terms of micro constituents. In each case assume that the specimen begins at 760°C. **(10 M)**

(a) Cool rapidly to 680°C , hold for 10^4 s, then quench to room temperature.

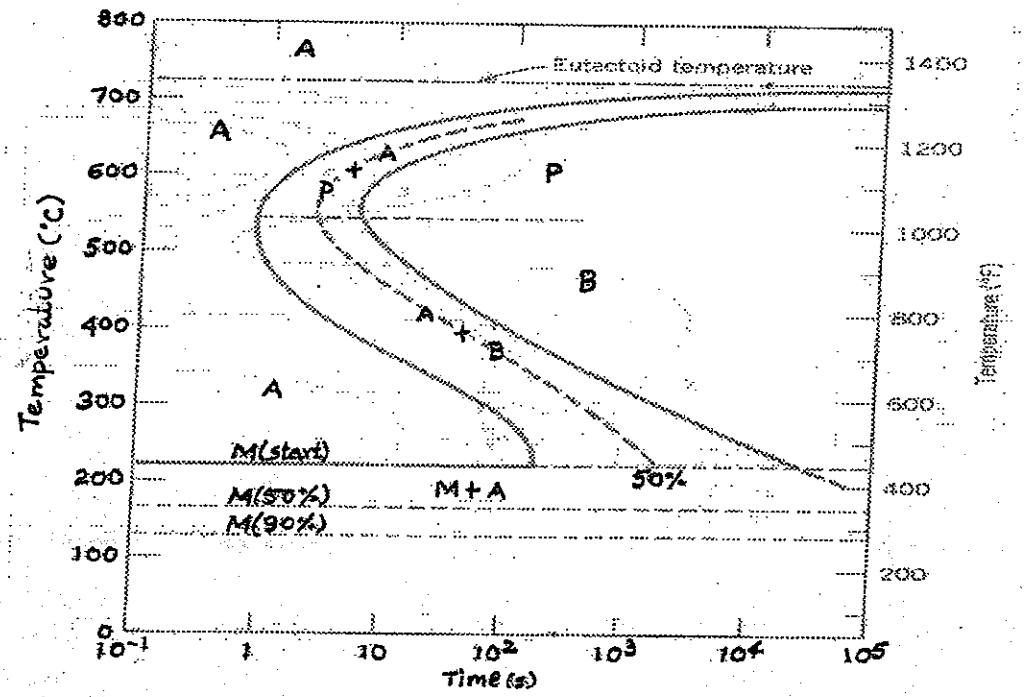
(b) Rapidly cool to 600°C , hold for 4 s, rapidly cool to 450°C , hold for 10 s, then quench to room temperature.

(c) Cool rapidly to 400°C , hold for 900 s, then quench to room temperature.

(d) Rapidly cool to 575°C , hold for 50 s, rapidly cool to 350°C , hold for 100 s, then quench to room temperature.

(e) Rapidly cool to 250°C , hold for 90 s, then quench to room temperature in water. Reheat to 315°C for 1 h and slowly cool to room temperature.

Fig. Q9



Part - C

Q10. (a) Is it possible to have a polytetrafluoroethylene homopolymer with the following molecular weight data and a weight average degree of polymerization of 485? Why or why not? Take atomic weights of Carbon, Fluorine and Hydrogen as 12.01 g/mol, 19 g/mol and 1.008 g/mol respectively.

(b) Also compute the number average degree of polymerization. **(10 M)**

Molecular weight range (g/mol)	x_i	w_i
5,000 – 10,000	0.05	0.11
10,000 – 15,000	0.16	0.17
15,000 – 20,000	0.24	0.26
20,000 – 25,000	0.28	0.22
25,000 – 30,000	0.20	0.14
30,000 – 35,000	0.07	0.10

Q11. How much sulfur must be added to 100 g of polyisoprene rubber to cross-link 5 percent of the mers? Assume all available sulfur is used and that only one sulfur atom is involved in each cross-linking bond. Atomic weight of sulfur = 32 g/mol. **(10 M)**

Q12. One half of an electrochemical cell consists of a pure nickel electrode in a solution of Ni^{2+} ions; the other is a cadmium electrode immersed in a Cd^{2+} solution. Half potentials of Cd and Ni are -0.403 V and -0.250 V respectively. Take Faraday constant as 96500 C/mol and gas constant as 8.314 J/mol-K.

(a) If the cell is a standard one, write the spontaneous overall reaction and calculate the voltage that is generated.

(b) Compute the cell potential at 25°C if the Cd^{2+} and Ni^{2+} concentrations are 0.5 M and 10^{-3} M respectively. **(10M)**

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DUBAI INTERNATIONAL ACADEMIC CITY, DUABI, UAE

Second Semester 2009-2010

TEST - 2 (Open book)

Year	: II year	Date	:25.04.2010
Course No.	: ES C242	Course Title	: Structure and Properties of Materials
Duration	: 50 min. Marks: 60	Weightage	: 20%

Note: (i) Answer all the questions.
(ii) Refer the prescribed text book for the required data and figures wherever necessary.
(iii) Only the prescribed text book and hand written class notes are permitted.

Q1. Consider a single crystal of Aluminum oriented such that the applied stress is along the direction [1 1 2].
a. Compute the resolved stress along (111) plane and its slip directions. **[8]**
b. Along which of the directions would the slip be preferred? **[3]**
c. If the critical resolved shear stress is 8.2 MPa, what is the applied stress? **[4]**

Q2. A brass wire is cold drawn 25 percent to a diameter of 1.10 mm. It is then further cold – rolled to 0.90 mm diameter.
a. What is the total percent cold reduction? Find the ductility, tensile strength and yield strength for brass at this percent of cold reduction. **[11]**
b. Also calculate the diameter of the wire if it is to be cold drawn with 33 percent cold reduction. **[4]**

Q3. For a brass alloy, the stress at which plastic deformation begins is 345 MPa and the modulus of elasticity is 103 GPa.
a. If it has a circular cross-sectional area of 130 mm^2, find the maximum load that can be applied to a specimen without plastic deformation. **[3]**
b. If its original length is 76 mm, find the work done to strain the wire without plastic deformation. **[6]**
c. If the Poisson's ratio of brass alloy is 0.34, find the lateral contraction in this material. **[6]**

Q4. For an alloy of composition 50 wt% Zn – 50 wt% Cu, cite the phases present and their mass fractions at the following temperatures:
900°C, 700°C, 500°C, 400°C, 300°C and 200°C. **[15]**

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Second Semester 2009-2010

TEST 1 – Regular (Closed book)

Class: II Year
Course No.: ES C242
Time duration: 50 min.
Marks: 75
Date:14.03.10
Course title: Structure and Properties of Materials
Weightage: 25%

Note: Answer all the questions.

Q1. The energy of the two atoms in the field of each other is given by $U(r) = -\frac{\alpha}{r} + \frac{\beta}{r^8}$ where 'α' and 'β' are constants and 'r' is the distance between the two centres of the atoms.

a) In order to have maximum stability for the pair, find the minimum distance between them. **[10 M]**

b) Let 'U_A' and 'U_R' represent the attractive energy and repulsive energy of the two atoms. If $U_A = n\ U_R$, find the value of n (where 'n' is an integer) for the pair of atoms to be stable. **[10 M]**

Q2. a) Derive linear density expressions for the FCC [0 $\bar{1}$0] and FCC [11 $\bar{1}$] directions in terms of atomic radius R. **[8 M]**

b) Compute the linear density values for the same two directions for copper with atomic radius of 0.128 nm. **[6 M]**

c) Calculate APF for a unit cell of copper (FCC). **[6 M]**

Q3. For the figure below a, b and c are the crystal parameters where α, β and γ are the angles between the axes. Given $a \neq b \neq c$ and $\alpha = \gamma = 90^\circ \neq \beta$

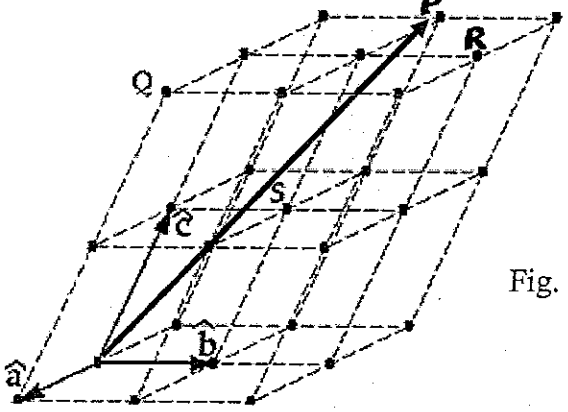


Fig. Q3

a) Identify the crystal system and structure **[2 M]**

b) What is the lattice point given by point R? **[3 M]**

c) What is crystallographic direction for the origin to P? **[3 M]**

Q4. The figure below (Fig.Q4) shows a FCC structure.

a) Mark the lattice point **264** and draw the direction [2 $\bar{6}$ 4] **[5 M]**

b) Identify the plane shown and draw the plane ($1\bar{1}1$). **[7 M]**

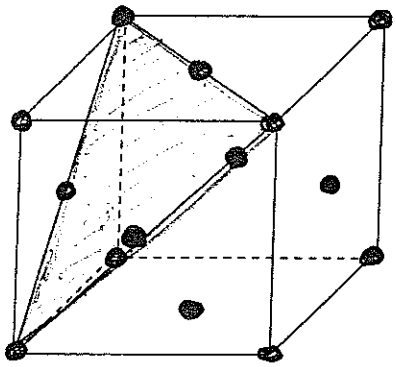


Fig. Q4

Q5. a) Draw the unit cell of CsCl showing the location of cesium and chlorine ions. **[5M]**

b) If the ionic radius of cesium is 0.170 nm and chlorine is 0.181 nm, compute the theoretical density of CsCl. Take A_{Cs} = 132.91 g/mol; A_{Cl} = 35.45 g/mol; Avogadro number = 6.023×10^{23} atoms/mol. **[10M]**

A

BITS, PILANI – DUBAI

2nd Year, SECOND SEMESTER 2009 – 2010

QUIZ - 2

Course Code:	**ES C242**	Date:	**11.05.2010**
Course Title:	**Structure and Properties of Materials**	Maximum Marks:	**21**
Duration:	**20 minutes**	Weightage:	**7 %**

Name _____

ID No: _____ **Program:** _____ **Section** _____

Instruction : ***Answer all the questions.***

Q1. Molecular weight data for a polymer is given below. Find the following:

a. number-average molecular weight

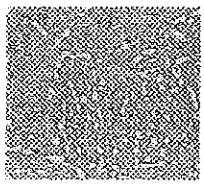
b. weight-average molecular weight **(3M)**

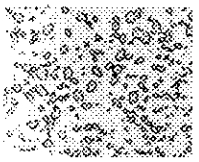
Molecular weight Range (g/mol)	x_i	w_i
16,000 – 24,000	0.48	0.30
24,000 – 32,000	0.24	0.40
32,000 – 40,000	0.28	0.30

Q2. Sketch portions of a linear polyvinylchloride molecule that are (a) syndiotactic, (b) atactic and (c) isotactic. **(3M)**

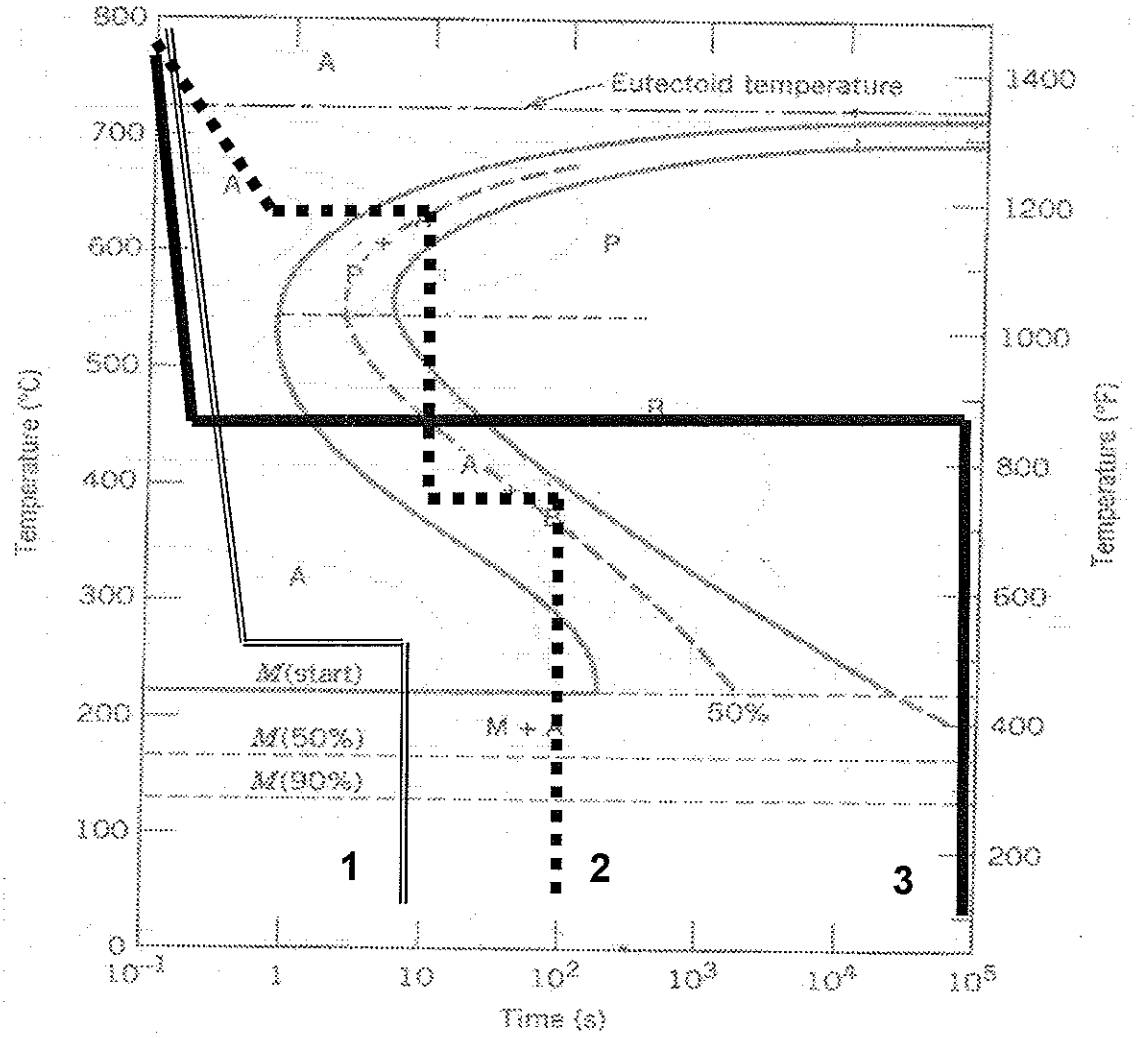
Q3. Sketch (a) cis and (b) trans mer structures for butadiene **(3 M)**

Q4. Following are different microstructures for an iron-carbon alloy of eutectoid composition. Name the microstructures. **(6 M)**





Q5. Name the final product that will be obtained at the end of the heat treatment process for the paths 1, 2 and 3 shown in the figure below. **(6 M)**



B

BITS, PILANI – DUBAI

2nd Year, SECOND SEMESTER 2009 – 2010

QUIZ - 2

Course Code:	**ES C242**	Date:	**11.05.2010**
Course Title:	**Structure and Properties of Materials**	Maximum Marks:	**21**
Duration:	**20 minutes**	Weightage:	**7 %**

Name _____

ID No: _____ **Program:** _____ **Section** _____

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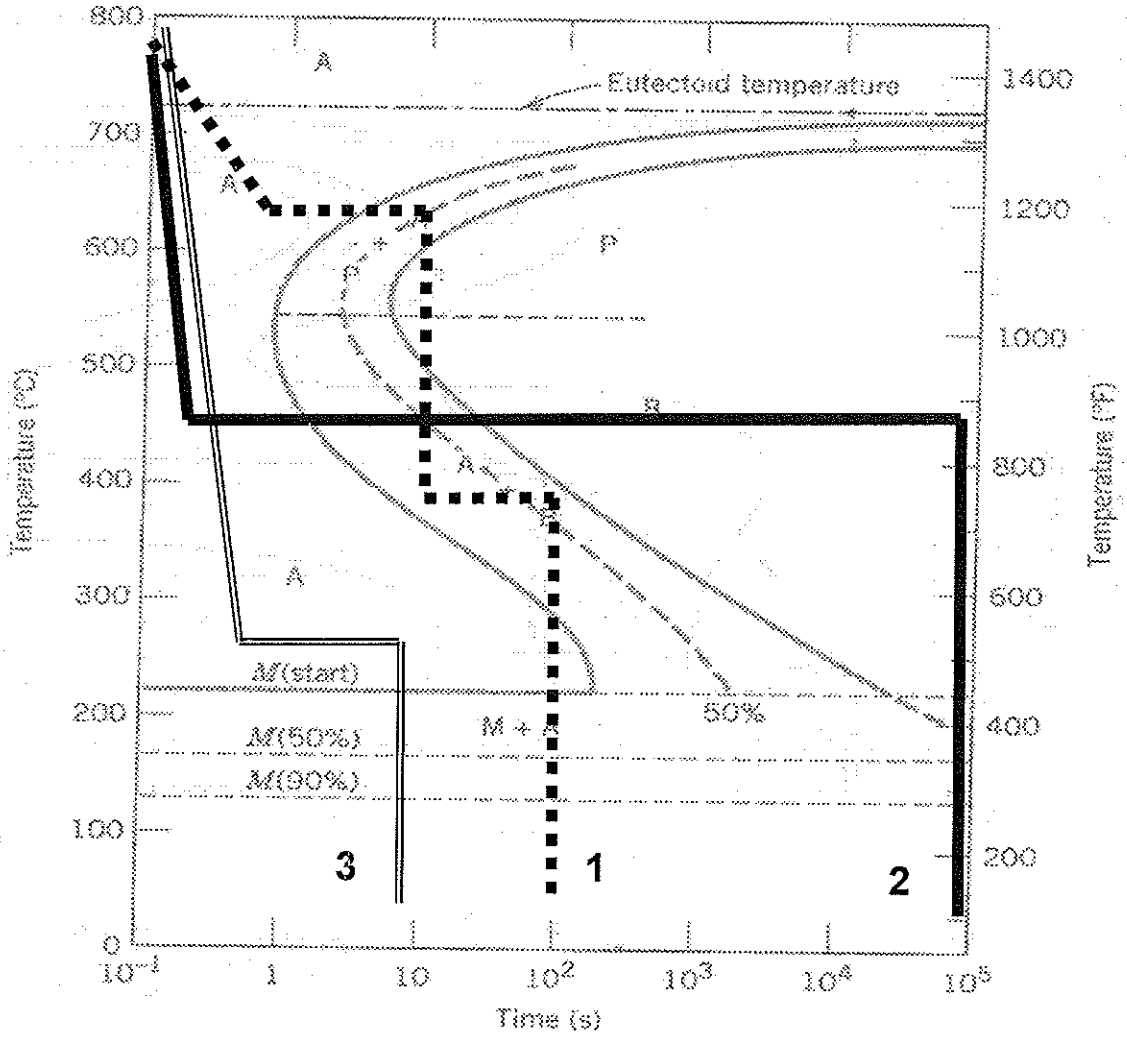

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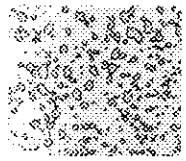
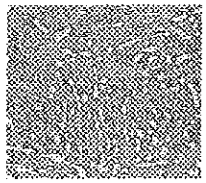
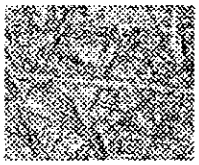






B

BITS, PILANI – DUBAI

2nd Year, SECOND SEMESTER 2009 – 2010

QUIZ - 1

Course Code:	**ES C242**	Date:	**30.03.2010**
Course Title:	**Structure and Properties of Materials**	Maximum Marks:	**8**
Duration:	**20 minutes**	Weightage:	**8 %**

Name _____

ID No: _____ **Program:** _____ **Section** _____

Instruction : *Answer all the questions.*

1. Calculate the fraction of atom sites that are vacant for pure copper at 500°C. Assume energy for vacancy formation of 0.90eV. (Take Boltzmann's constant, $k = 8.62 \times 10^{-5}$ eV/atom-K)

2. Determine the approximate density of an alloy that contains 33.3 wt% Ag, 62.7 wt% Au and 4 wt% Cu. Given the densities of Ag, Au and Cu as 10.49g/cm^3, 19.32 g/cm^3 and 8.94 g/cm^3 respectively.

3. Calculate the mass of hydrogen that has to pass through a 0.3 m^2 plate in 2 hours at 500°C when the diffusion flux is 4.5×10^{-6} kg/m^2-s.

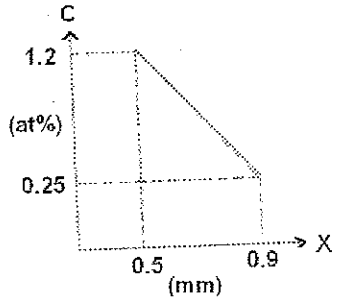
4. Below, atomic radius, crystal structure, electronegativity and the valence are tabulated for a few elements. Which of these elements would you expect to form a substitutional solid solution having complete solubility with copper?

Element	Atomic Radius (nm)	Crystal structure	Electronagativity	valence
Copper	0.1278	FCC	1.9	+2
Iron	0.1241	BCC	1.8	+2
Nickel	0.1246	FCC	1.8	+2
Aluminium	0.1431	FCC	1.5	+3
Platinum	0.1387	FCC	2.2	+2
Lead	0.1376	FCC	2.2	+2

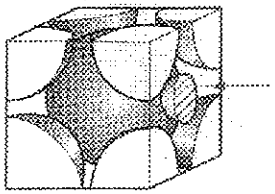
5. Find the value of the diffusion coefficient for the diffusion of carbon in α-iron at 900°C from the data given below. (Take R = 8.31 J/mol-K)

Diffusing species	Host metal	Do (m^2/s)	Activation energy (kJ/mol)
C	α-Fe	2.3×10^{-5}	148

6. Find the concentration gradient for the diffusion path given below.



7. Calculate the radius of the interstitial atom in the BCC iron lattice shown in the figure below. The atomic radius of an iron atom is 0.129 nm.



8. Find the time taken for the case hardening done on a steel gear exposed to a carbon rich atmosphere at 600°C given the following data.

$D_{600°C}$	5.9×10^{-12} m^2/s
$D_{900°C}$	5.3×10^{-11} m^2/s
$t_{900°C}$	900 minutes