BITS Pilani, Dubai Campus

II Year II Semester 2013 - 14

Comprehensive Exam (Closed Book)

Course No. CHE F243 **Course Title:** Materials Science and Engineering

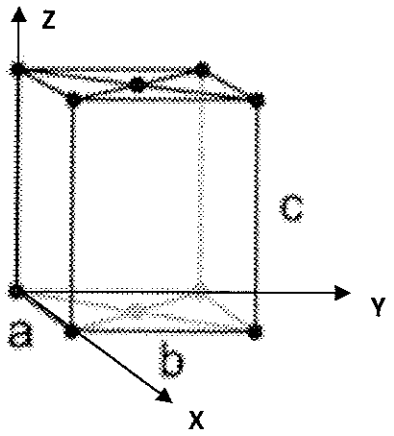
Date: 29-05-2014 **Max.Marks:** 80

Weightage: 40 % **Duration:** 3 Hours

Notes:

- Answer all the questions.
- Make suitable assumptions if required and clearly state them
- e = 1.602 x 10^{-19} C , ε_o = 8.85 x 10^{-12} F/m, N_A = 6.022 x 10^{23}atoms /mol,
- R = 8.31 J/mol or 8.62 x 10^{-5}ev/atom-mol
- Atomic weight of carbon = 12 g/mol and Fluorine = 19 g/mol

1. Duckium (Du), an important hypothetical material, has the base-centered orthorhombic crystal structure. The unit cell is illustrated by the adjacent figure. In the orthorhombic unit cell, all angles are 90°. In the case of Duckium a = b = c/2. In the base centered structure, the top and bottom faces each have a centered atom. The diagonal on each of these two faces is a close-packed direction.



   a) How many atoms per unit cell are there in Du? Clearly show how you arrive at this answer.
   b) Derive an equation for the atomic packing fraction of the Du structure and solve this.
   c) Derive planar density expression for (1 1 0) in terms of atomic radius R.
   d) The atomic radius of a Du atom is 1.160 x10^{-10} m. The density of Du is 5.00 g/cm^3. Determine its atomic weight. Show your work. **[8 M]**

2. Suppose the interatomic potential energy between two atoms of the hypothetical element is given by:

$$U(r) = 2\varepsilon\left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{2}\right]$$

   where r is the interatomic distance. Given, ε = 0.4850 eV and σ = 0.2800 nm. From the equation above, derive an expression for the equilibrium interatomic spacing, r_o, in terms of the constant σ. Calculate r_o. **[4 M]**

3. A single crystal of a metal that has the FCC crystal structure is oriented such that a tensile stress is applied parallel to **[100]** direction. If the critical resolved shear stress for this material is 1.75 MPa, calculate the magnitude(s) of applied stress (es) necessary to cause slip to occur on the **(111)** plane in each of the $[1\bar{1}\,0]$, $[10\bar{1}]$ and $[01\bar{1}]$ directions. **[10 M]**

(P.T.O)

4. Nitrogen from a gaseous phase is to be diffused into pure iron at 700°C. If the surface concentration is maintained at 0.1 wt% N, what will be the concentration 1 mm from the surface after 10 h? The diffusion coefficient for nitrogen in iron at 700°C is 2.5×10^{-11} m^2/s. **[8 M]**

Table 6.1 Tabulation of Error Function Values

z	$erf(z)$	z	$erf(z)$	z	$erf(z)$
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

5. What is the composition, in atom percent, of an alloy that contains 20,185 g of silver, 37,966 g of gold, and 2,404 g of Cu. The atomic weights of silver, gold and copper are 107.87 amu, 196.97 amu and 63.55 amu respectively. **[8 M]**

6. A tensile test is performed on a metal specimen, and it is found that a true plastic strain of 0.20 is produced when a true stress of 575 MPa is applied; for the same metal, the value of the strain hardening coefficient is 860 MPa. Calculate the true strain that results from the application of a true stress of 600 MPa. **[8 M]**

7. An electrochemical cell is constructed such that on one side a pure nickel electrode is in contact with a solution containing Ni^{2+} ions at a concentration of 3×10^{-3} M. The other cell half consists of a pure Fe electrode that is immersed in a solution of Fe^{2+} ions having a concentration of 0.1 M. At what temperature will the potential between the two electrodes be +0.140 V? The standard potentials are $V^{\circ}_{Fe} = -0.440$ V and $V^{\circ}_{Ni} = -0.250$ V. **[8 M]**

8. Consider a carbon fiber reinforced epoxy composite. The fibers are continuous, unidirectional aligned and 60% by volume. The tensile strength of carbon strength of carbon fibers is 3 GPa, and the Young's modulus is 250 GPa. The tensile strength of the epoxy matrix is 50 MPa, and its Young's modulus is 3 GPa. Compute the Young's modulus and the tensile strength of the composite in the longitudinal direction. **[4 M]**

(P.T.O)

9. The molecular weight data for a poly tetrafluro ethylene material are tabulated

Molecular weight	X_i	W_i
10,000-20,000	0.03	0.01
20,000-30,000	0.09	0.04
30,000-40,000	0.15	0.11
40,000-50,000	0.25	0.23
50,000-60,000	0.22	0.24
60,000-70,000	0.14	0.18
70,000-80,000	0.08	0.12
80,000-90,000	0.04	0.07

Compute (i) the number – average molecular weight (ii) the weight-average molecular weight, and (iii) both the degree of polymerization. **[10 M]**

10. a) Using the isothermal transformation diagram for an iron-carbon alloy of eutectoid composition (figure is given), determine the final microstructure (in terms of micro constituents present & approximate percentages). **[6 M]**

(i) Cool rapidly to 650°C, left for 10^2 s, then quench to room temperature

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

(iii) Cool rapidly to 500°C, hold for 10^5 s, then quench to room temperature

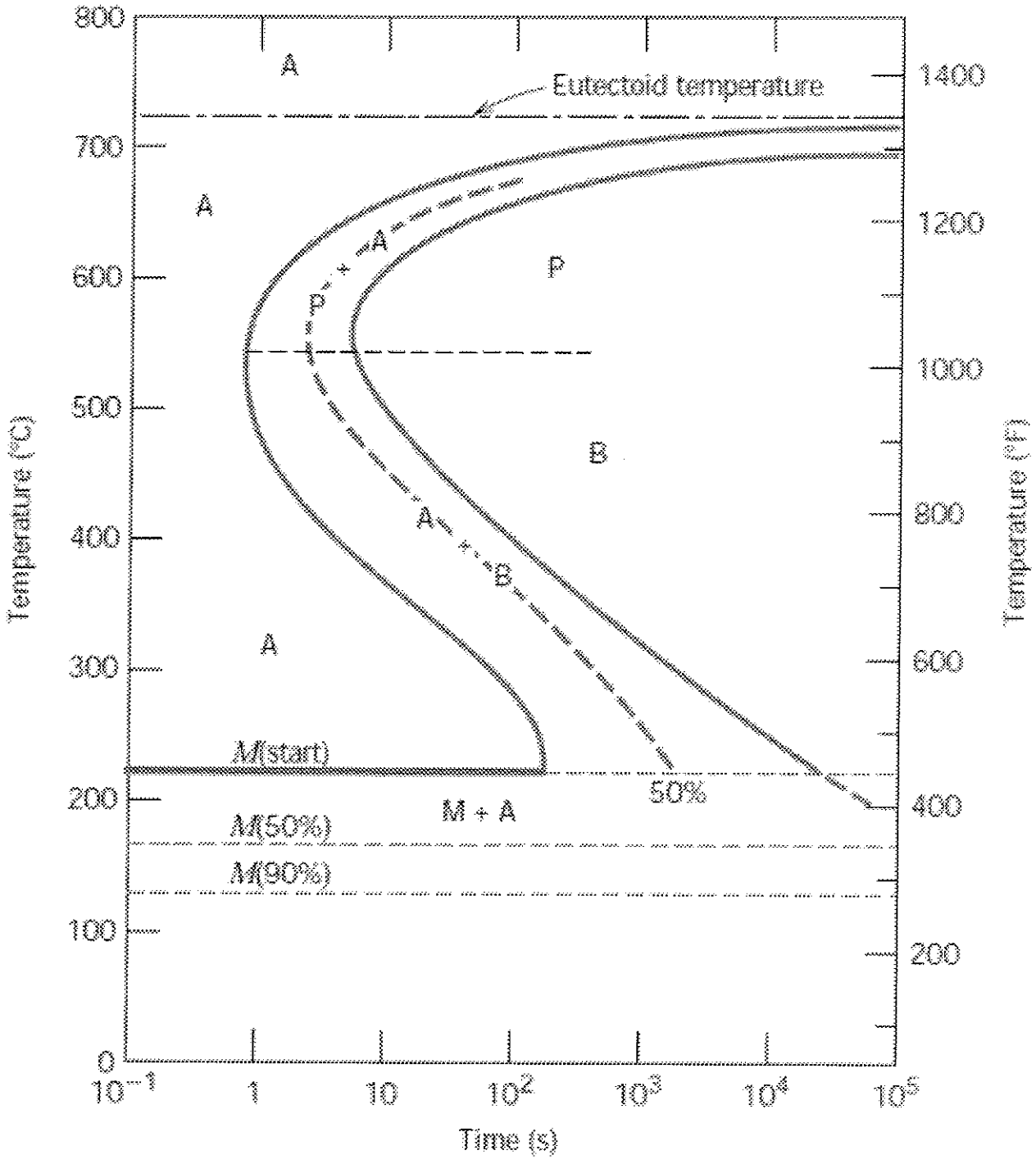
b) Make a copy of the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition (Figure 10.13) and then sketch and label on this diagram time–temperature paths to produce the following microstructures: **[6 M]**

(iv) 100% tempered martensite.

(v) 50% coarse pearlite, 25% bainite, and 25% martensite.

(vi) 50% bainite and 50% pearlite

10. Use the following diagram for answering Q.No. 10 and attach it with answer booklet



BITS Pilani, Dubai Campus

II Year II Semester 2013-2014

Test No.2 (Open Book)

Course No. CHE F243 **Course Title:** Materials Science and Engineering

Date: 29-4-2014 **Max.Marks:** 40

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

Notes:

- Answer all the questions.
- Draw neat sketches wherever necessary.
- Make suitable assumptions if required and clearly state them

1. The kinetics of the austenite-to-pearlite transformation obey the Avrami relationship. Using the reaction transformed–time data given below, determine the total time required for 95% of the austenite to transform to pearlite **[6 M]**

Fraction Transformed	*Time (s)*
0.2	280
0.6	425

2. For a 99.6 wt% Fe-0.40 wt% C steel at a temperature just below the eutectoid, determine the following. Also use the attached graph for answering the following
   - i) The compositions of Fe_3C and ferrite (α).
   - ii) The amount of cementite (in grams) that forms in 100 g of steel.
   - iii) The amounts of pearlite and proeutectoid ferrite (α) in the 100 g. **[9 M]**

3. The mass fraction of the α phase, W_α, is defined as $W_\alpha = \frac{m_\alpha}{m_\alpha + m_\beta}$. Derive the equation $W_\alpha = \frac{V_\alpha \rho_\alpha}{V_\alpha \rho_\alpha + V_\beta \rho_\beta}$, where V_α, is volume fraction of phase α, defined by $V_\alpha = \frac{v_\alpha}{v_\alpha + v_\beta}$.

   The volumes of the respective phases in the alloy are v_α and v_β and ρ's denote densities. **[8 M]**

(P.T.O)

4. From the curves shown in the following diagram, determine the rate of crystallization for pure copper at the shown temperatures. **[5 M]**

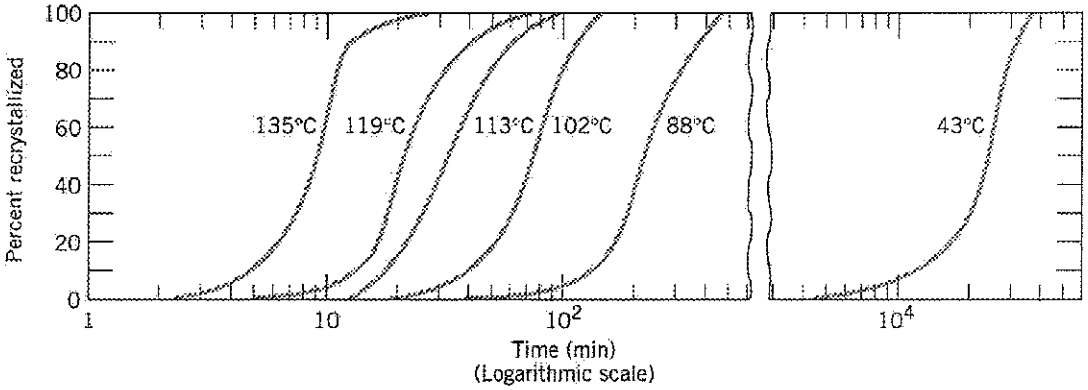


FIGURE 10.2 Percent recrystallization as a function of time and at constant temperature for pure copper. (Reprinted with permission from *Metallurgical Transactions,* Vol. 188, 1950, a publication of The Metallurgical Society of AIME, Warrendale, Pennsylvania. Adapted from B. F. Decker and D. Harker, "Recrystallization in Rolled Copper," *Trans. AIME,* **188,** 1950, p. 888.)

5. Is it possible to have a poly(vinyl chloride) homopolymer with the following molecular weight data, and a number average degree of polymerization of 1120? Why or why not?

Molecular weight Range (g/mol)	w_i	x_i
8,000 – 20,000	0.02	0.05
20,000 – 32,000	0.08	0.15
32,000 – 44,000	0.17	0.21
44,000 – 56,000	0.29	0.28
56,000 – 68,000	0.23	0.18
68,000 – 80,000	0.16	0.10
80,000 – 92,000	0.05	0.03

[8 M]

6. The number-average molecular weight of a poly(styrene-butadiene) alternating copolymer is 135,000 g/mol; determine the average number of styrene and butadiene mer units per molecule. **[4 M]**

Use this for Q2. Detach and attach with the answer booklet.

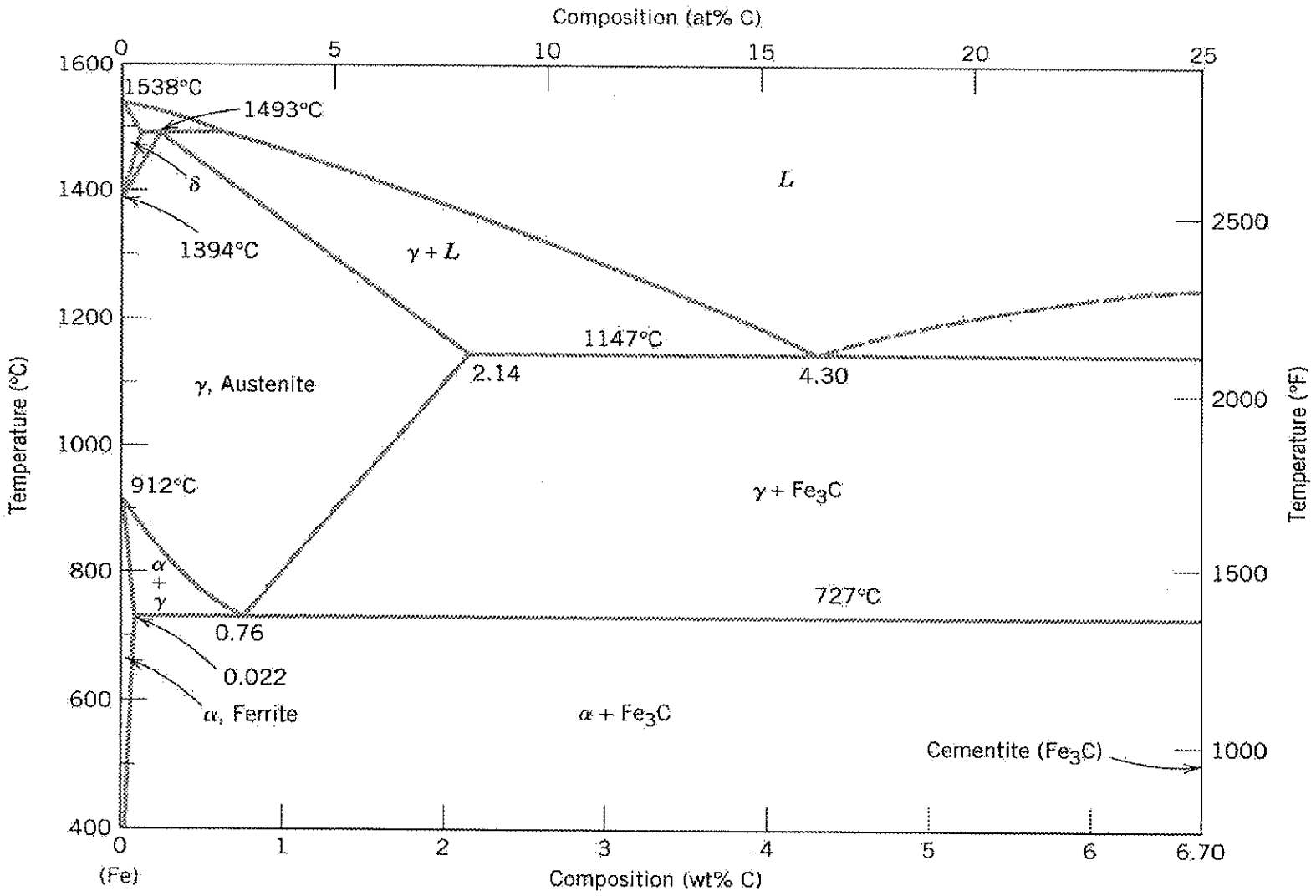


FIGURE 9.21 The iron–iron carbide phase diagram. [Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 1, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

BITS Pilani, Dubai Campus

II Year II Semester 2013-2014

Test No.1 (Closed Book)

Course No. CHE F243 **Course Title:** Materials Science and Engineering

Date: 4-3-2014 **Max.Marks:** 50

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

Notes:

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

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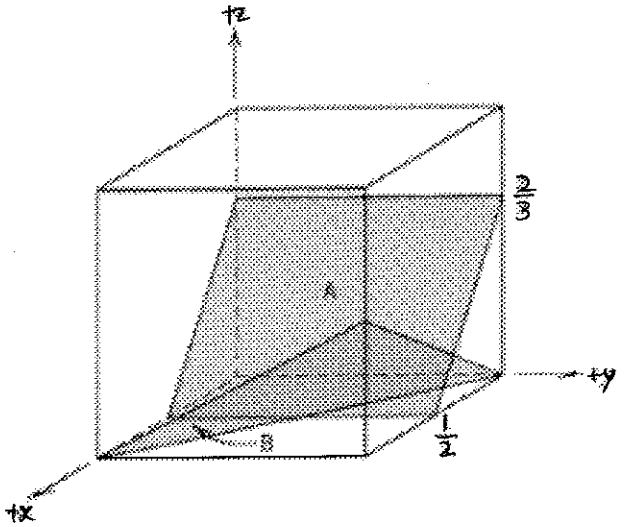
1. The potential energy (E_N) of two atoms forming a covalent bond a distance r apart is given by:

$$E_N = -\frac{A}{r} + \frac{B}{r^n}$$

where n= 10. Determine the constants A and B if the two atoms form a stable molecule at r_o= 0.35 nm and E_N (r_o) = – 6.13 eV. **[10 M]**

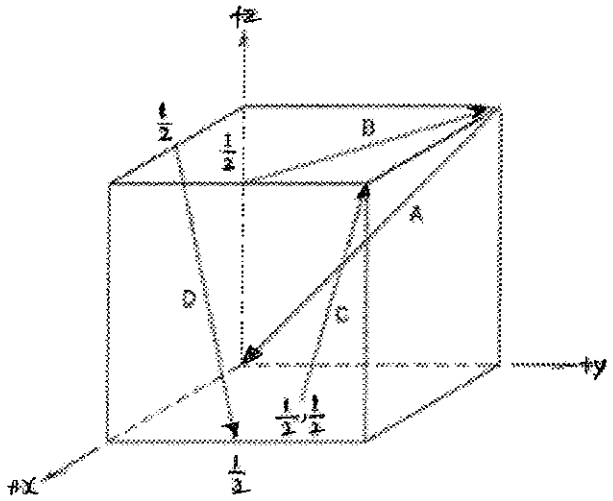
2. Niobium has atomic radius of 0.1430 nm, atomic weight of 92.92 g/mol and a density of 8.57 g/cm^3. Determine its crystal structure. **[10 M]**

3. Determine the Miller indices for the planes shown in the following unit cell: **[10 M]**



(P. T. O)

4. Determine the indices for the directions shown in the following cubic unit cell: **[10 M]**



5. Silicon Carbide (SiC) is a ceramic material with the so-called zinc blende crystal structure. It can be constructed from the FCC unit cell using a two atom basis consisting of a Si atom at (0,0,0) and a C at (¼, ¼, ¼).
   a) Calculate the percent ionicity of the Si-C bond. The electronegativity of Si and C are 1.8 and 2.5 respectively.
   b) Determine the number of Si atoms and the number of C atoms contained in each SiC unit cell. **[10 M]**

A

BITS Pilani, Dubai Campus

Dubai International Academic City, Dubai, UAE

II Year, SECOND SEMESTER, 2013 – 14

QUIZ – 2

Course code: **CHE F243**
Course Title: **Materials Science and Engineering**
Duration: **20 minutes**

Date: **Surprise**
Maximum Marks : **14**
Weightage: **7%**

Name _____

ID No: _____ **Section** _____

Note: (i) Answer ALL Questions. (ii) Answers without units will be marked wrong.

1. Dislocation motion is associated with **[1 M]**
   a. plastic deformation in an amorphous solid;
   b. plastic deformation of a crystalline solid;
   c. elastic deformation of an amorphopus solid;
   d. elastic deformation of a crystalline solid;
   e. all of the above.

   ANS

2. _____ is a measure of resistance to plastic deformation exhibited by a material. **[1 M]**

3. The recrystallization of a cold-worked metal by annealing at an elevated temperature **[1 M]**
   a. increases its yield strength;
   b. increases its hardness;
   c. decreases its ductility;
   d. lowers the total strain energy because of the lower dislocation density;
   e. none of the above.

   ANS

4. The critical resolved shear stress for iron is 27 MPa. Determine the maximum possible yield strength for a single crystal of Fe pulled in tension. **[1 M]**

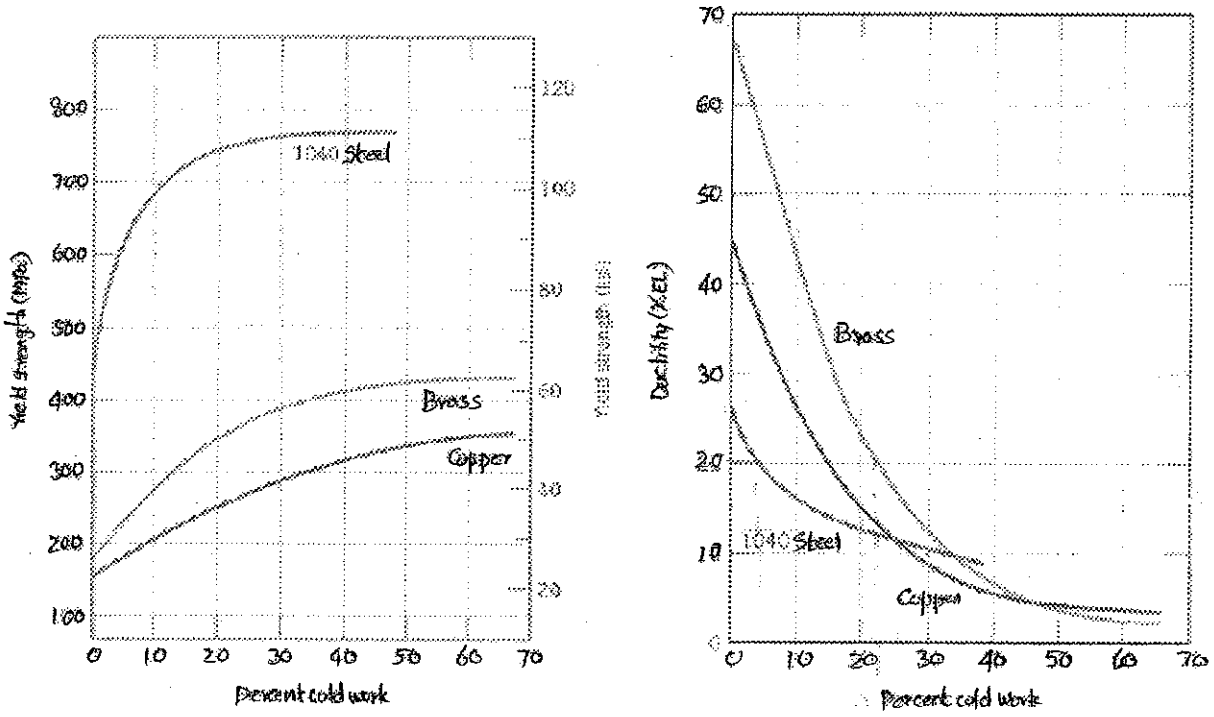
(PTO)

5. The electrical resistivity of single-crystal Si is less than that of polycrystalline Si, because
   a. poly-Si has more impurities
   b. the temperature dependence of resistivity is greater in poly-Si
   c. grain boundaries increase the frequency of electron scattering
   d. the vacancy concentration in poly-Si is higher
   e. none of the above. **[1 M]**

ANS

6. Heat capacity of most materials is approximately equal to _____.**[1 M]**

7. It is necessary to select a metal alloy for an application that requires a yield strength of least 310 MPa while maintaining a minimum ductility at (% EL) of 28%. If the metal may be cold worked, decide which of the following are candidates: copper, brass and 1040 steel. **[1 M]**



ANS

8. The material with lowest resistivity is **[1 M]**
   a) constantan b)silver c) manganin d) nichrome.

ANS

9. A steel rod has a length of exactly 20 cm at 30°C. How much longer is it at 50°C? Use $\alpha_{Steel} = 11 \times 10^{-6}/°C$. **[1 M]**

10. A certain substance has a mass per mole of 50 g/mole. When 314 J of heat is added to a 30.0 g sample of this material, its temperature rises from 25.0◦C to 45.0◦C.
(a) What is the specific heat of this substance? **[1 M]**

(b) How many moles of the substance are present? **[1 M]**

11. An uncold-worked brass specimen of average grain size 0.01mm has a yield strength of 150 Mpa.
a) Determine the constant k_y, if it is known that the value of σ_o is 25 MPa. **[2 M]**

b) Estimate the yield strength for the same brass material if the grain size is 0.016 mm. **[1 M]**

A

BITS Pilani, Dubai Campus

Dubai International Academic City, Dubai, UAE

II Year, SECOND SEMESTER, 2013 – 14

QUIZ – 1

Course code:	**CHE F243**	Date:	**25.3.14**
Course Title:	**Materials Science and Engineering**	Maximum Marks :	**16**
Duration:	**20 minutes**	Weightage:	**8%**

Name _____

ID No: _____ **Section** _____

Note: (i) Answer ALL Questions. (ii) Take $N_A = 6.023 \times 10^{23}$ atoms/mole. (iii) R = 8.62×10^{-5} eV/atom-K

1. For each of the following stacking sequences found in FCC metals, cite the type of defect that exists by indicating the position(s) of defect(s) with a vertical dashed line.

   a) .....A B C A B C B A C B A .....

   b) .....A B C A B C B C A B C.....

   [1 M]

   ANS a)

   b)

2. The _____ mechanism contributes very little to the diffusivity . **[1 M]**

3. Example for steady-state diffusion **[1 M]**
   a) Hydrogen purification by palladium sheet
   b) Doping semi-conductors
   c) Corrosion resistance of duralumin
   d) Decarburization of steel

   ANS

4. Determine the number of atomic sites for silver in atoms per cubic meter. The atomic weight and density (at 800 °C) for silver are, respectively, 107.9 g/mol and 9.5 g/cm^3.

   [2 M]

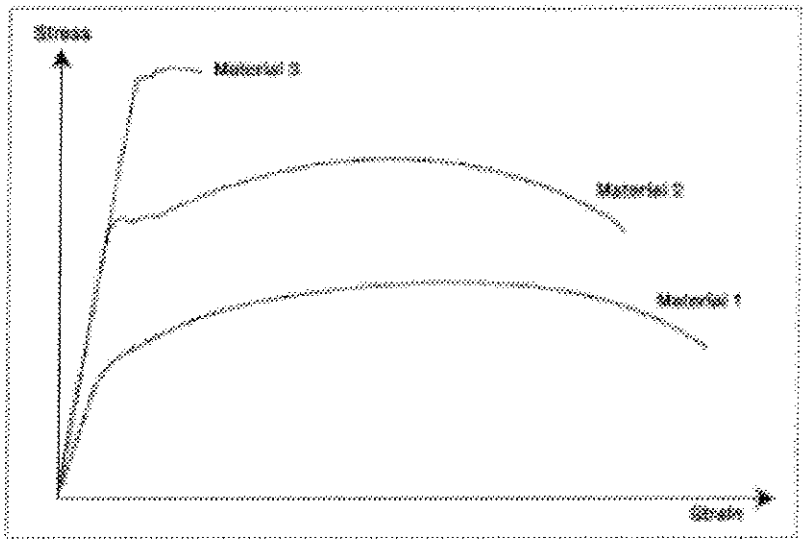
5. Engineering stress-strain curve and True stress-strain curve are equal up to

_____ **[1 M]**

6. True stress-strain curve need to be corrected after

_____ **[1 M]**

7. Using the given diagram, identify which material has **[2M]**



a. The highest yield stress **ANS**

b. The highest tensile stress` **ANS**

c. The highest ductility **ANS**

d. The highest modulus **ANS**

8. A steel alloy cylindrical rod of 100 mm long and 10 mm diameter is subjected to a stress of 350 MPa, produces a strain of 5.1×10^{-4}. If the modulus of elasticity is 207 GPa, find its Poisson's ratio.

[2 M]

9. Compute the number of kilograms of hydrogen that pass per hour through a 5-mm thick sheet of palladium having an area of 0.20 m^2 at 500°C. Assume a diffusion coefficient of 1.0×10^{-8} m^2/s, that the concentrations at the high- and low pressure sides of the plate are 2.4 and 0.6 kg of hydrogen per cubic meter of palladium, and that steady-state conditions have been attained.

[3 M]

10. For a bronze alloy, the stress at which plastic deformation begins is 280 MPa, and the modulus of elasticity is 115 GPa. Find the modulus of resilence. [2 M]