# BITS PILANI, DUBAI CAMPUS

FIRST SEMESTER 2011- 2012

II YEAR

COMPREHENSIVE EXAM

**Course Code:** ES C242 **Date:** 11.01.2012

**Course Title:** Structure and Properties of Materials **Max Marks:** 80

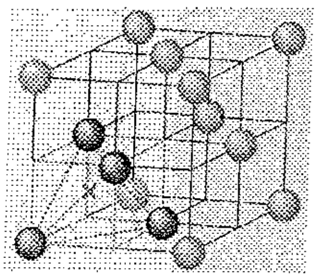
**Duration:** 3 hours **Weightage:** 40%

## PART A

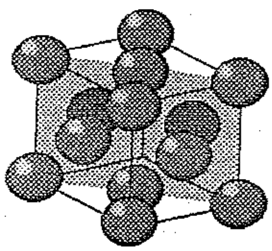
1. Compute the percentage ionic character of interatomic bond for each of the following compounds: MgO. **[8M]**

2. A) Within a cubic unit cell, sketch the following **[8M]**
   a) direction $[3\bar{1}3]$
   b) planes $(3\bar{1}2)$

   B) Represent the following planes, showing both anions and cations:
   a) (111) Plane for the zinc blend crystal structure



   b) (110) plane for perovskite crystal structure



3. Copper and Platinum both have the FCC crystal structure, and Cu forms a substitutional solid solution for concentrations upto approximately 6 wt% Cu at room temperature. Compute the unit cell edge length for 95% Pt – 5 wt% Cu alloy. **[8M]**

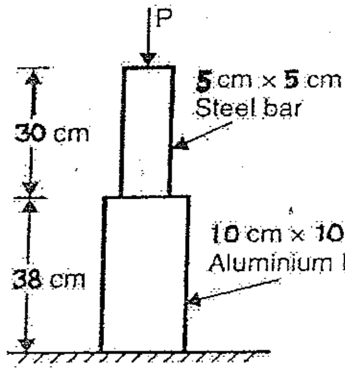
4. In copper-nickel diffusion couple after a 500-h heat treatment at 1000°C(1273 K) the concentration of Ni is 3.0 wt% at the 1.0 mm position within the copper. At what

temperature should the diffusion couple be heated to procedure this same concentration (i.e. 3.0 wt% Ni) at a 2.0-mm position after 500 h? The pre-exponential and activation energy for the diffusion of Ni in Cu are $2.7 \times 10^{-4}$ $m^2/s$ and 236,000 J/mol, respectively. **[8M]**

5. Consider a single crystal of some hypothetical metal that has the FCC crystal structure and is oriented such that a tensile stress is applied along a $[\bar{1}02]$ direction. If slip occurs on a (111) plane and in a $[\bar{1}01]$ direction, compute the stress at which the crystal yields if its critical resolved shear stress is 3.42 MPa. **[8M]**

## PART B

6. A member formed by connecting a steel bar to an aluminium bar is shown in Figure below. Assuming that the bars are prevented from buckling sideways, calculate the magnitude of force 'P' that will cause the total length of the member to decrease 0.25 mm. The values of elastic modulus for steel and aluminium are $2.1 \times 10^5 \ N/mm^2$ and $7 \times 10^4 N/mm^2$ respectively. **[8M]**




7. Molecular weight data for polytetrafluoroethylene are tabulated here. Compute **[8M]**
   (a) the number-average molecular weight,
   (b) the weight-average molecular weight and
   (c) number-average degree of polymerization

| Molecular wt. Range | $x_i$ | $w_i$ |
|---|---|---|
| 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 |

8. For a copper-silver alloy of composition 25 wt% Ag-75 wt% Cu and at 775°C (1425°F) do the following: [8M]
(a) Determine the mass fractions of α and β phases.
(b) Determine the mass fractions of primary α and eutectic microconstituents.
(c) Determine the mass fraction of eutectic α.

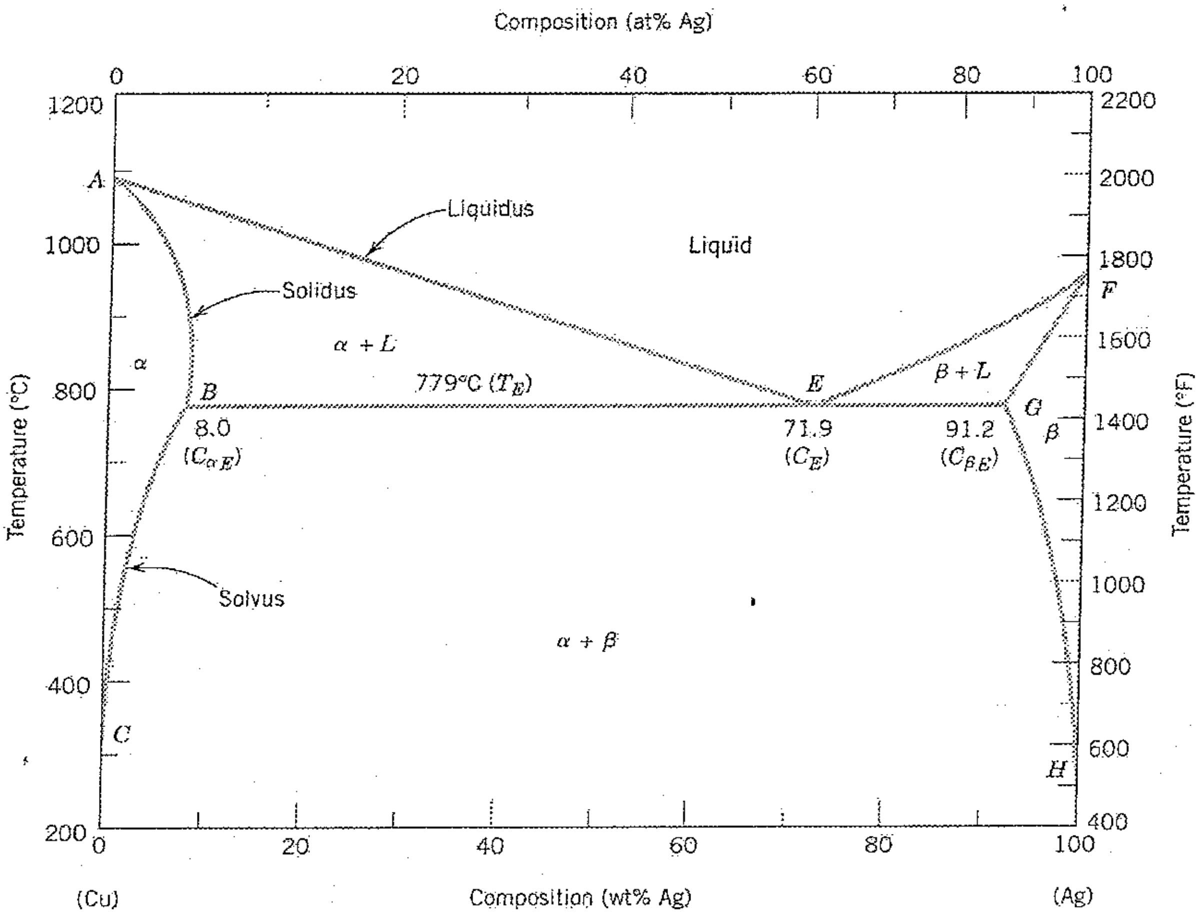



FIGURE 9.6 The copper–silver phase diagram. [Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 1, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

9. An $Fe/Fe^{2+}$ concentration cell is constructed in which both electrodes are pure iron. The $Fe^{2+}$ concentration for one cell half is 0.5 *M*, for the other, $2 \times 10^{-2}$ *M*. Is a voltage generated between the two cell halves? If so, what is its magnitude and which electrode will be oxidized? If no voltage is produced, explain this result. **[8M]**

10. Using the isothermal transformation diagram for a 1.13 wt% C steel alloy, **(figure attached)**, given determine the final microstructure (in terms of just the micro constituents present) of a small specimen that has been subjected to the following time-temperature treatments. In each case assume that the specimen begins at 920°C, and that it has been held at this temperature long enough to have achieved a complete and homogenous austenitic structure. **[8M]**

a. Rapidly cool to 250°C, hold for $10^3$ s, then quench to room temperature.
b. Rapidly cool to 775°C, hold for 500 s, then quench to room temperature.
c. Rapidly cool to 400°C, hold for 500 s, then quench to room temperature.
d. Rapidly cool to 700°C, hold for $10^5$ s, then quench to room temperature.
e. Rapidly cool to 650°C, hold for 3 s, rapidly cool to 400°C, hold for 25 s, then quench to room temperature.
f. Rapidly cool to 350°C, hold for 300 s, then quench to room temperature.
g. Rapidly cool to 675°C, hold for 7 s, then quench to room temperature.
h. Rapidly cool to 600°C, hold for 7 s, rapidly cool to 450°C, hold for 4 s, then quench to room temperature.

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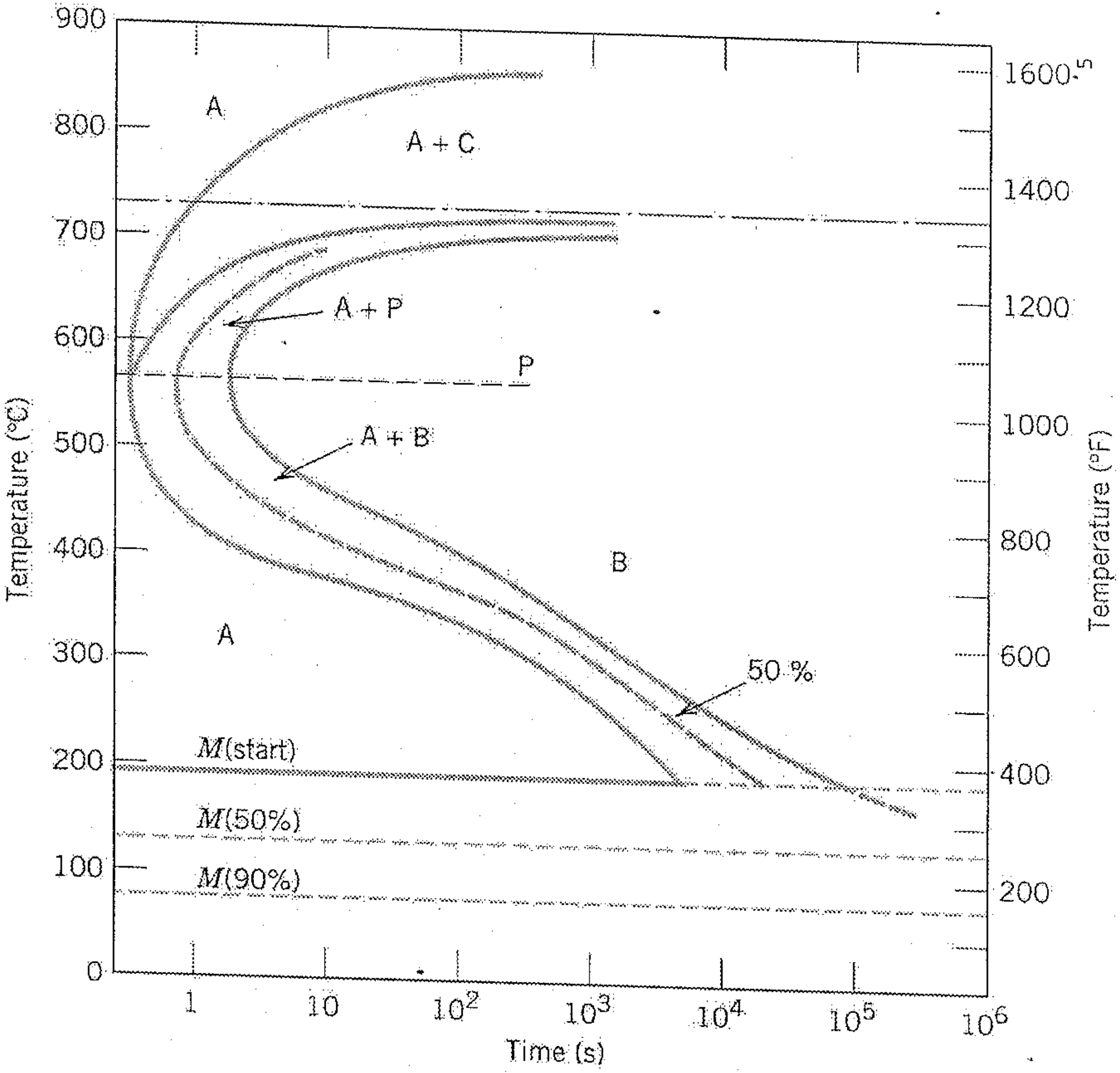
**ATTACH THIS DIAGRAM TO ANSWERSHEET '*PART B*'**

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

**FIRST SEMESTER 2011- 2012**

II YEAR [Open Book]

Test II

**Course Code:** ES C242 **Date:** 18.12.2011

**Course Title:** Structure and Properties of Materials **Max Marks:** 40

**Duration:** 50 minutes **Weightage:** 20%

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Q1. Cite the phases that are present and the phase compositions for the following alloys from the Fig. 1.

(a) 90 wt% Zn-10 wt% Cu at 400°C (750°F)

(b) 2.12 kg Zn and 1.88 kg Cu at 500°C (930°F) **[15]**

Q2. . Using the isothermal transformation diagram for a 1.13 wt% C steel alloy, determine the approximate percentage of the micro constituents that form. In each case assume that the specimen begins at 920°C, and that it has been held at this temperature long enough to have achieved a complete and homogenous austenitic structure. [Fig2.] **[15]**

a. Rapidly cool to 250°C, hold for $10^3$ s, then quench to room temperature.

b. Rapidly cool to 400°C, hold for 50 s, then quench to room temperature.

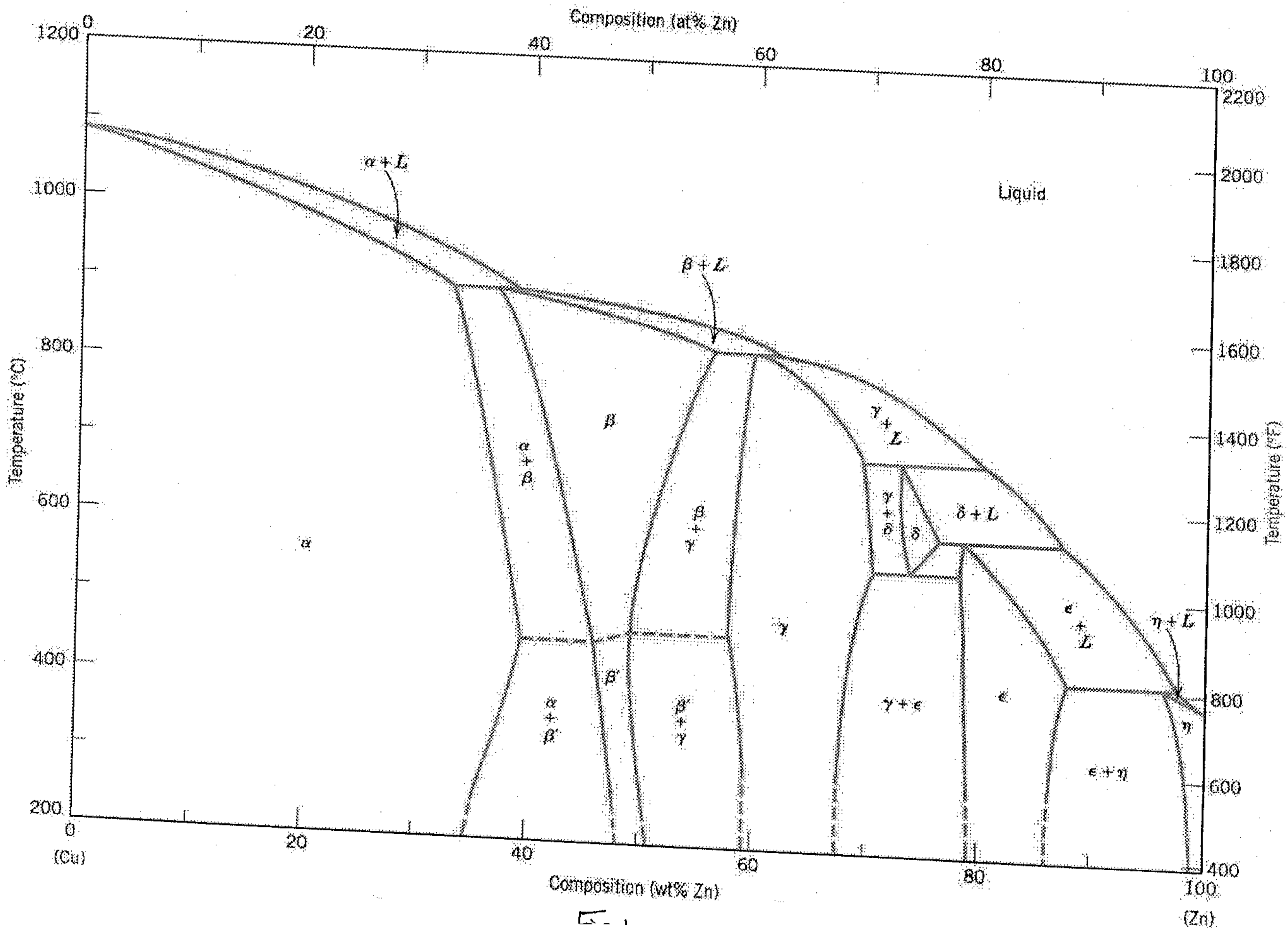
c. Rapidly cool to 700°C, hold for $10^5$ s, then quench to room temperature.

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

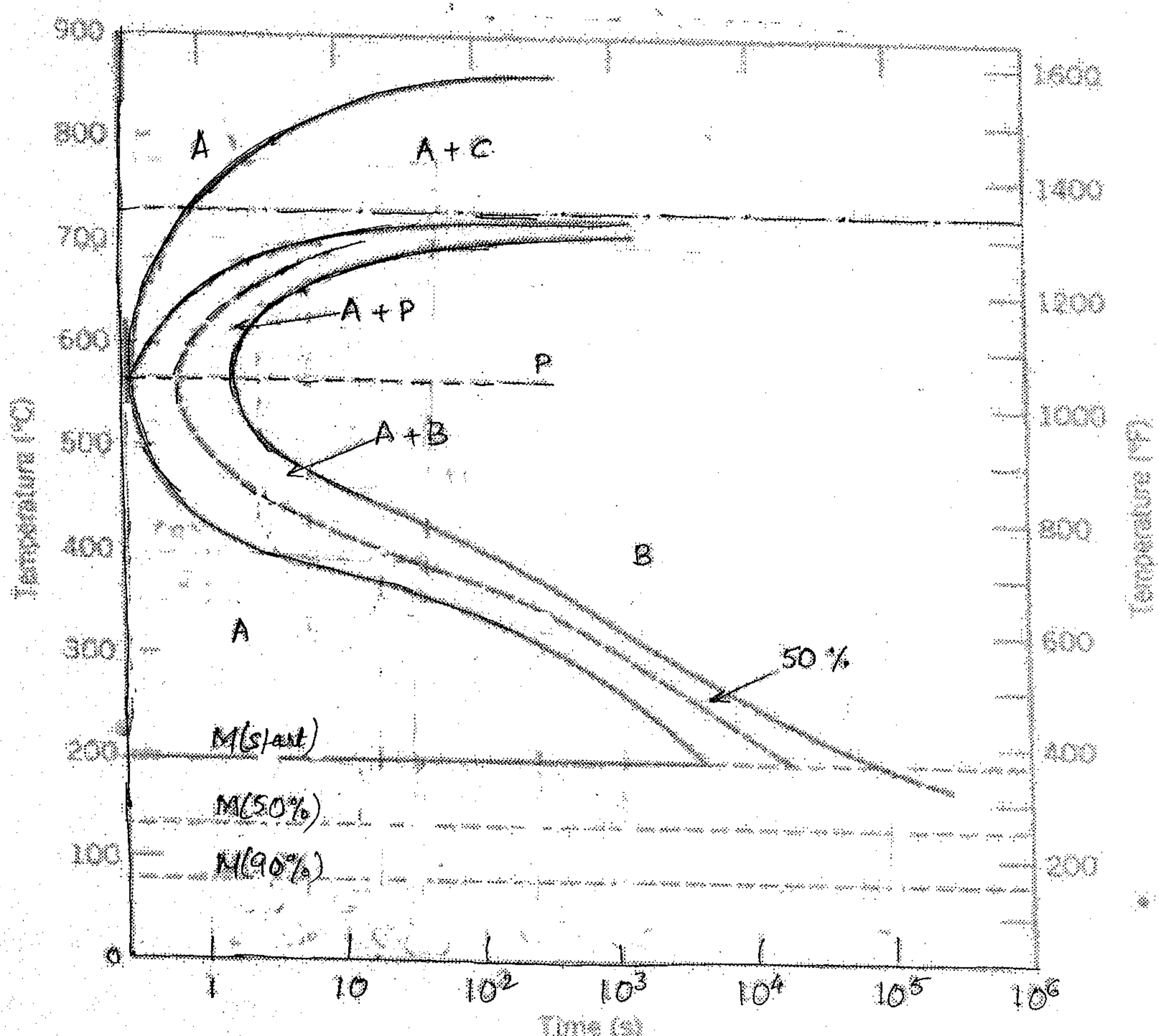
e. Rapidly cool to 600°C, hold for 7 s, rapidly cool to 450°C, hold for 4 s, then quench to room temperature.

Q3. An $Fe/Fe^{2+}$ concentration cell is constructed in which both electrodes are pure iron. The Fe2+ concentration for one cell half is 0.5 *M*, for the other, $2 \times 10^{-2}$ *M*. Is a voltage generated between the two cell halves? If so, what is its magnitude and which electrode will be oxidized? If no voltage is produced, explain this result. **[5]**

Q4. An electrochemical cell is composed of pure copper and pure lead electrodes immersed in solutions of their respective divalent ions. For a 0.6 M concentration of $Cu^{2+}$, the lead electrode is oxidized yielding a cell potential of 0.507 V. Calculate the concentration of $Pb^{2+}$ ions if the temperature is 25°C. **[5]**



Composition (at% Zn)
0
20
40
60
80
100
1200
1000
800
600
400
200
Temperature (°C)
2200
2000
1800
1600
1400
1200
1000
800
600
400
Temperature (°F)
Liquid
α + L
β + L
γ + L
δ + L
ε + L
η + L
α
α + β
β
β + γ
γ
γ + δ
δ
α + β′
β′
β′ + γ
γ + ε
ε
ε + η
η
0
(Cu)
20
40
60
80
100
(Zn)
Composition (wt% Zn)


A
A + C
A + P
P
A + B
B
A
50 %
M(start)
M(50%)
M(90%)
Temperature (°C)
Temperature (°F)
Time (s)
0
100
200
300
400
500
600
700
800
900
200
400
600
800
1000
1200
1400
1600
1
10
$10^2$
$10^3$
$10^4$
$10^5$
$10^6$
[Fig 2]

# BITS PILANI, DUBAI CAMPUS

## FIRST SEMESTER 2011- 2012

II YEAR

**Course Code:** ES C242 Test - I **Date:** 23.10.2011

**Course Title:** Structure and Properties of Materials **Max Marks:** 50

**Duration:** 50 minutes **Weightage:** 25%

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Q1. Derive planar density expression for BCC (110) plane in terms of atomic radius R. **[6]**

Q2. Find the critical radius ratio for triangular coordination **[10]**

Q3. Calculate the density of MgO from the following data. **[10]**

Structure: FCC anion packing, cations in octahedral voids

Radius of $Mg^{2+}$ = 0.78 Å

Radius of $O^{2-}$ = 1.32 Å

Q4. A sheet of steel 1.5 mm thick has nitrogen atmospheres on both sides at 1200°C and is permitted to achieve a steady-state diffusion condition. The diffusion coefficient for nitrogen in steel at this temperature is $6 \times 10^{-11}$ $m^2/s$, and the diffusion flux is found to be $1.2 \times 10^{-7}$ $kg/m^2$-s. Also, it is known that the concentration of nitrogen in the steel at the high-pressure surface is 4 $kg/m^3$. How far into the sheet from this high-pressure side will the concentration be 2 $kg/m^3$? Assume a linear concentration profile. **[12]**

Q5. The diffusion coefficient for magnesium in aluminum at 500°C is $4.15 \times 10^{-14}$ $m^2/s$. What time will be required at 600°C to produce the same diffusion result (in terms of concentration at a specific point) as for 10 h at 500°C? Assume preexponential and activation energy at 600°C for the diffusion coefficient are $6.5 \times 10^{-5}$ $m^2/s$ and 136 kJ/mol respectively. Given R = 8.31 J/mol-K **[12]**

9, 413-2

# BITS PILANI, DUBAI CAMPUS

**FIRST SEMESTER 2011- 2012**

II YEAR

**Course Code:** ES C242 **Date:** 06.12.2011

**Course Title:** Structure and Properties of Materials **Max Marks:** 14

**Duration:** 20 minutes **Weightage:** 7%

**Name:** .............................. **ID No:** ........................ **Sec** .....

1. (a) From the given plot of yield strength versus (grain diameter)$^{-1/2}$ for a 70 Cu–30 Zn cartridge brass, determine values for the constants $\sigma_0$ and $k_y$.

(b) Now predict the yield strength of this alloy when the average grain diameter is $1.0 \times 10^{-3}$ mm.

**[7]**

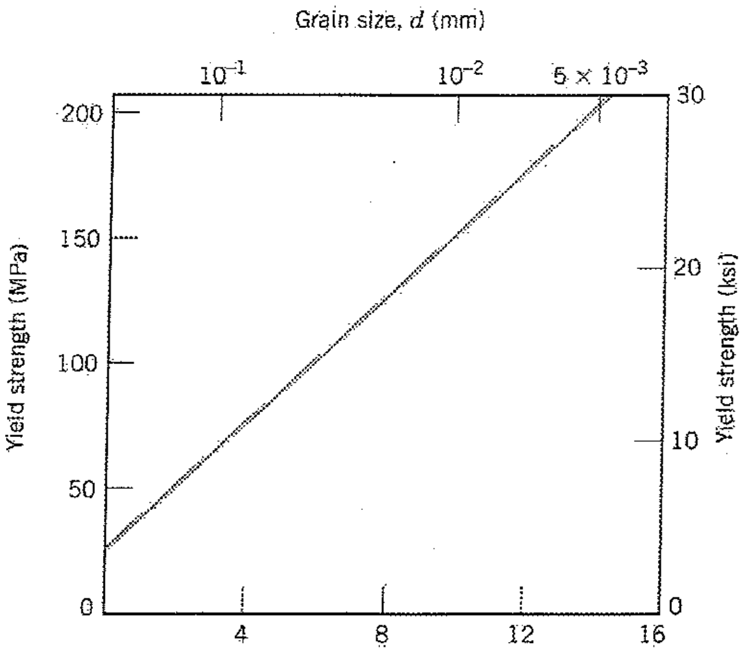


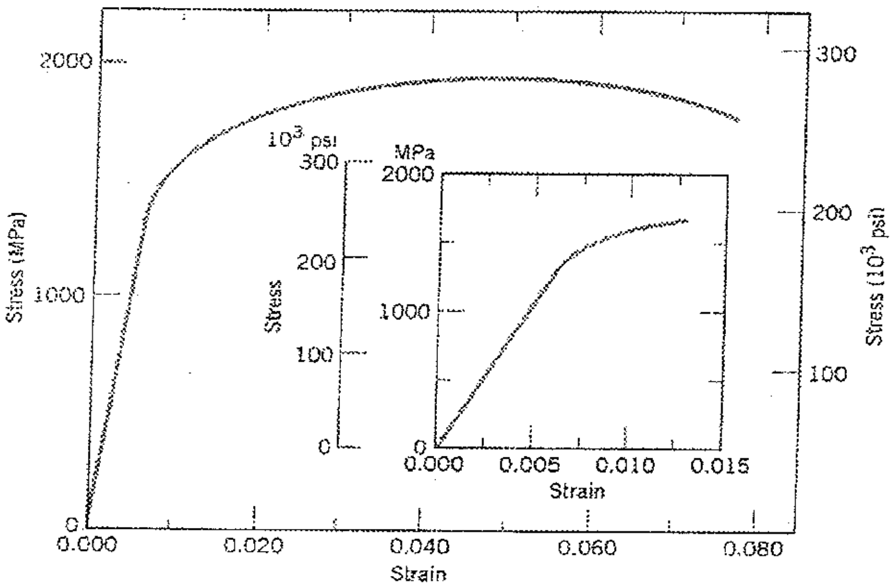

Figure 7.13 The influence of grain size on the yield strength of a 70 Cu–30 Zn brass alloy. Note that the grain diameter increases from right to left and is not linear. (Adapted from H. Suzuki, "The Relation Between the Structure and Mechanical Properties of Metals," Vol. II, *National Physical Laboratory, Symposium No. 15*, 1963, p. 524.)

2. The figure shows the tensile engineering stress-strain behavior for steel alloy.

**[7]**

a) What is the modulus of elasticity?
b) What is the proportional limit?
c) What is the yield strength at a strain off-set of 0.0022?
d) What is the tensile strength?
e) What is the percentage ductility?

Figure 6.24 Tensile stress–strain behavior for an alloy steel.



gw3-1

# BITS PILANI, DUBAI CAMPUS

**FIRST SEMESTER 2011- 2012**

II YEAR

**Course Code:** ES C242 **Date:** 27.09.2011

**Course Title:** Structure and Properties of Materials **Max Marks:** 8

**Duration:** 20 minutes **Weightage:** 8%

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

{$\varepsilon_0 = 8.85 \times 10^{-12}$ F·m$^{-1}$; $e = 1.602 \times 10^{-19}$ C}

Q1. Calculate the force of attraction between a $Fe^{3+}$ and an $O^{2+}$ ion the centers of which are separated by a distance of 1.40 nm. Calculate the corresponding energy. **(2)**

Q2. Fill in the blanks with the appropriate answer. **(1)**

i) The Modulus of Elasticity, E, of a material is ____________ if the Binding Energy, $E_o$, is smaller.

ii) Coefficient of thermal expansion, $\alpha$, is larger if Binding Energy, $E_o$, is __________.

Q3. An **α**-iron has a BCC crystal structure and an atomic radius of 0.1241 nm. Compute its lattice parameter, **a.** **(1)**

Q4. Within a cubic unit cell, sketch the [$\bar{2}$12] direction **(1)**

Ans.

Q5. Draw the plane, on a cubit unit cell, whose Miller indices are (020) **(1)**

Ans

Q6. Calculate the Miller indices for the following plane **(2)**