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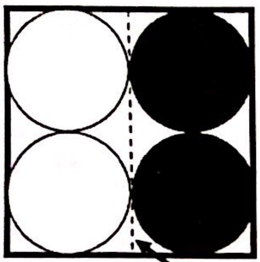
Name: **Entry No.:**

Question 1 **[15]**

a) Below diagram shows two sets of balls, initially separated so that the white balls are to the left and the black balls to the right. Write down how many distinguishable possible ways there are for this initial configuration. Now the membrane is removed and the balls can be placed anywhere in the four possible positions. Determine with the help of sketches the number of distinguishable possible ways in which the balls can now be placed. Hence determine the entropy of mixing, ΔS_{mix}, associated with the change from the initial to the mixed configuration. **[10]**



Membrane

No. of black balls = 2
No. of white balls = 2.
Let distinguishable possible ways of arrangement be W.

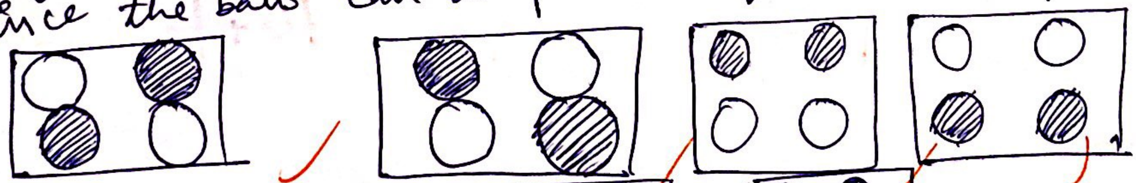
$S = k \ln W$

No. of total places: 4.

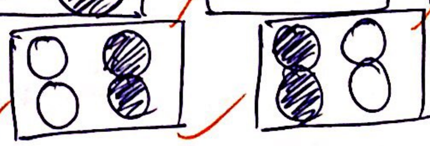
~~$w_i = \frac{4!}{2!\,2!} = \frac{3\times 4}{2} = 6$~~

$\boxed{w_i = 1}$

~~Diffusion will take place due to p~~ since the balls can be placed anywhere, these are possible:



$\boxed{W_f = 6}$



9

$\Delta S_{mix} = S_{\cancel{initial}\ final} - S_{\cancel{final}\ initial}$

$= k \ln \frac{w_{\cancel{i}\,f}}{w_{\cancel{f}\,i}} = 1.38\times 10^{-23} \ln\left(\frac{1}{6}\right)$

~~ΔS_{mix} 1.91×10^{-23} $J K^{-1}$~~

$\boxed{\Delta S_{mix} = 2.47\times 10^{-23}\ J K^{-1}}$

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b) The cable of a hoist has a cross section of 80 mm². The hoist is used to lift a crate weighing 500 kg. What is the stress in the cable? The free length of the cable is 3 m. How much will it extend if it is made of: (i) Steel (E = 200 GPa); (ii) Polypropylene (E = 1.2 GPa)? **[5]**

$A = 80\ mm^2 = 80 \times 10^{-6}\ M^2$

$F = 500kg = 500 \times 9.81 = 4905\ N$

Engineering stress $= \frac{F}{A} = \frac{4905}{80} \times 10^6 = 61.3125 \times 10^6\ N/M^2$ ✓

$l_o = 3M$

(i) $E = 200 \times 10^9\ Pa$

$E = \frac{\text{Stress}}{\text{Strain}} \Rightarrow$ strain $= \frac{\Delta l}{l_o} = \frac{61.3125 \times 10^6}{200 \times 10^9}$

$\Delta l = 0.306 \times 3 \times 10^{-3}$

~~0.918 MM~~

$= \underline{0.918\ MM}$ ✓

(ii) $E = 1.2\ GPa = 1.2 \times 10^9\ Pa.$

Strain $= \frac{\Delta l}{l_o}$ ✓

$\Delta l = \frac{61.3125 \times 10^6}{1.2 \times 10^9} \times 3 = \underline{153.28\ MM}$ ✓

5 good.

Scanned with CamScanner

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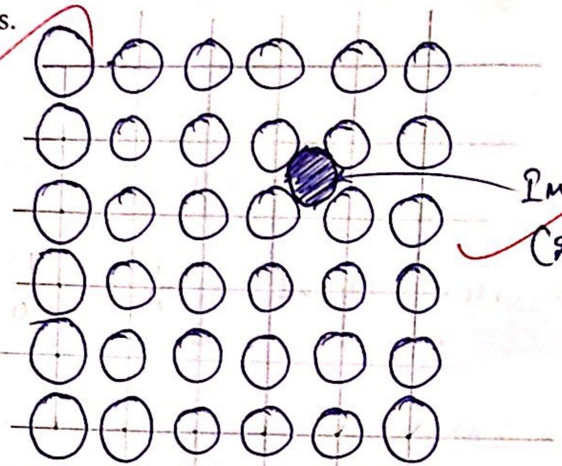
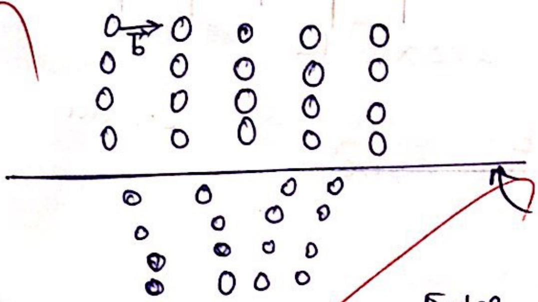
Question 2 [15]

a) Schematically show one each in point defect, line defect, area defect and volume defect. Name the sketched defects. [6]

Point defect:



Line defect:



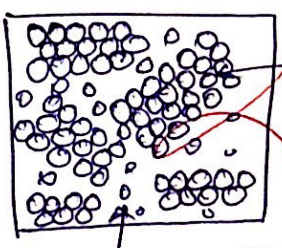
Edge dislocation

3.5

Area defect: surface defect.

Sketch?!

Volume defect:



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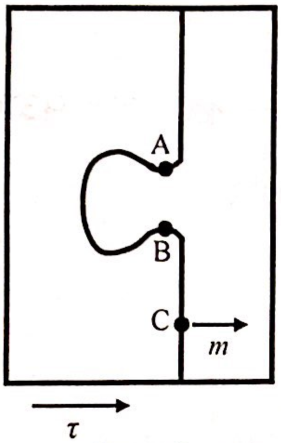
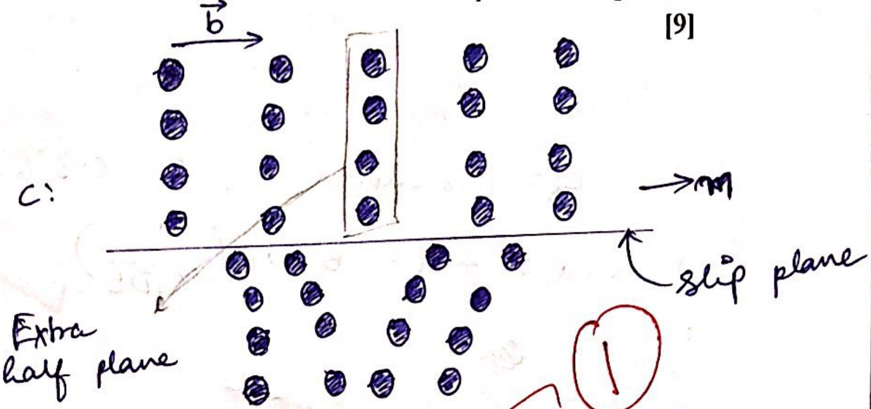
b) Shown in the below diagram is a dislocation line on its slip plane. The direction of slip motion, under the influence of the resolved shear stress (τ), is shown by arrow m at segment C. The segment C of the dislocation line is a positive edge dislocation. Sketch the characteristics of the segment C. Find the nature and character of segments A and B of the dislocation line and sketch them as well. Also show the direction of slip of these segments. **[9]**



C:



1

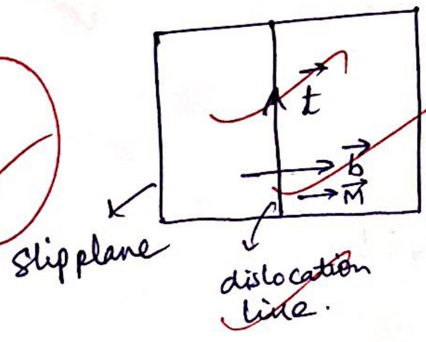
At C, the $\vec{b}$ is along $\vec{m}$, which will be invariant.

1

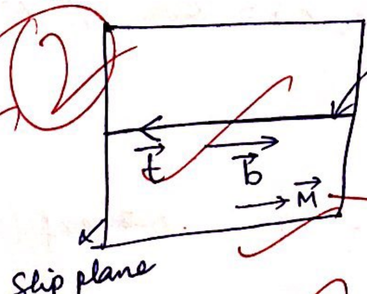
At B, $\overleftarrow{t}$ $\vec{b}$ [negative screw dislocation]

At A, $\vec{t}$ $\vec{b}$ [positive screw dislocation]

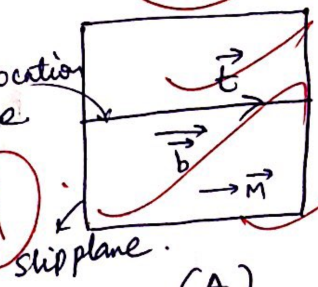
1.5



2



2



1

(A) Positive screw dislocation

(B) Negative Screw Dislocation

(C) Edge dislocation

0.5 deducted for missing slips.

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Question 3

[15]

a) At 937 °C, what is the time required to carburize a steel with an initial composition of 0.3% C to 0.6% C at a depth of 0.25 *mm*? Assume a constant surface concentration of 1% C due to the carburizing atmosphere. Given the following:

Diffusion Process	D_0, $10^{-4}\ m^2\ s^{-1}$	Q, $kJ\ mol^{-1}$
C in α-Fe	0.008	83
C in γ-Fe	0.7	157

You may assume $erf(\theta) = \theta$.

$C_s = 1\%$ Cabron , $C_1 = 0.3\%$. , $T = 937°C$.

$\Rightarrow \quad C(x,t) = A - B\,erf\left(\frac{x}{2\sqrt{Dt}}\right)$

At $T = 937°C$,

γ-phase of the steel (Fe) will exist.

$A = C_s = 1\%$

$B = C_s - C_1 = 1 - 0.3 = 0.7\%$

$$\left.\begin{aligned} C(x,0) &= C_1 \quad ; x > 0. \\ C(x,\infty) &= C_s \quad ; x > 0. \end{aligned}\right\} \text{For calculation of A and B.}$$

$$C(x,t) = 1 - 0.7\,erf\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$\Rightarrow \quad \frac{0.6-1}{-0.7} = erf\left(\frac{x}{2\sqrt{Dt}}\right)$$

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$$\Rightarrow \quad erf(0) = 0$$

$$\frac{x}{2\sqrt{Dt}} = 0.571$$

$x = 0.25\,mm$

$$\frac{0.25 \times 10^{-3}}{2\sqrt{D \times t}} = 0.571$$

$$\Rightarrow \quad Dt = (0.219 \times 10^{-3})^2$$

$$Dt = 0.048 \times 10^{-6}.$$

$$D = D_0 \exp\left(-\frac{Q}{RT}\right)$$

$$D = 0.7 \exp\left(-\frac{157 \times 10^3}{8.314 \times 1210}\right)$$

$$D = 1.17 \times 10^{-7}$$

$$t = \frac{0.048 \times 10^{-6}}{1.17 \times 10^{-7}} = 0.41\ s.$$

10+1

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Question 4 [15]

a) From the $Cu - Zn$ alloy phase diagram provided below: [1 + 2 + 3.5 + 1.5 + 2]

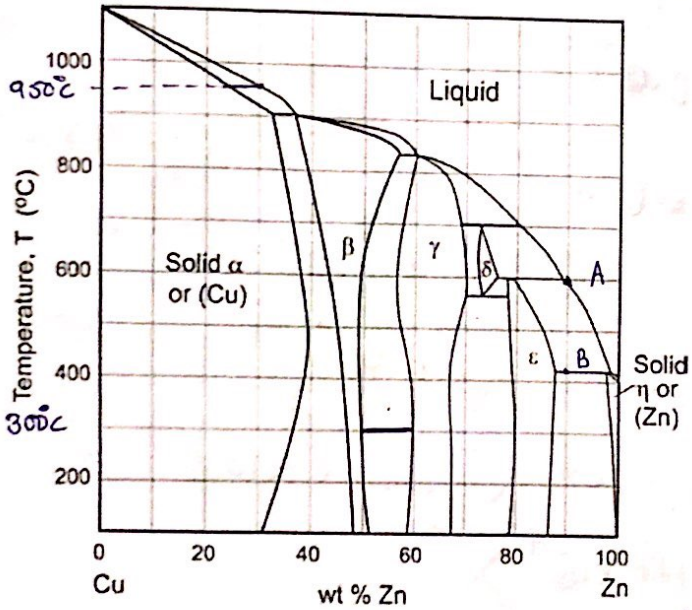
i) Find the approximate composition of the liquid which is in equilibrium with α at 950 °C.

ii) Determine the temperature (approximately) at which solidification begins and is completed for an alloy of 90 wt.% Zn slowly cooled from the liquid phase.

iii) Determine the phases present and their compositions and estimate the phase fractions in an alloy of 55 wt.% Zn held in equilibrium at 300 °C.

iv) List all the thermodynamic variables for an alloy having liquid and α phases in equilibrium.

v) Write in full, giving the compositions of all equilibrium phases, the invariant reaction taking place at ~700 °C. Name the reaction.



(i). Composition of Liquid : 30% Zn (wt) 1

(ii). solidification begins at A : 600°C
solidification completes at B : ≈ 420°C 2

(iii). Phases present : β + γ
$C_0 = 55\%$, $C_\beta = 50\%$, $C_\gamma = 60\%$
$f_\beta = \frac{60-55}{60-50} = \frac{5}{10} = 0.5$, $f_\gamma = \frac{55-50}{60-50} = 0.5$ 3.5
0.5

(iv). Temperature (T) +?

(v). $\gamma + L \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \delta$
(C=70%) (C=80%) (C≈73%) 2
Peritectic reaction

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b) Consider a hypo-eutectic alloy composition in the *Pb–Sn* phase diagram. [2 + 3]

i) Mention the composition of the considered alloy.

ii) Mention the different phase fields, including the initial and the final one, the considered alloy passes through when cooled from high temperature (~350 °C) to a temperature below the eutectic temperature.

iii) Sketch separately the microstructure of the alloy in each of the phase fields and label their phases.

(i). ~~Assumed~~ composition of the alloy: Pb, Sn.

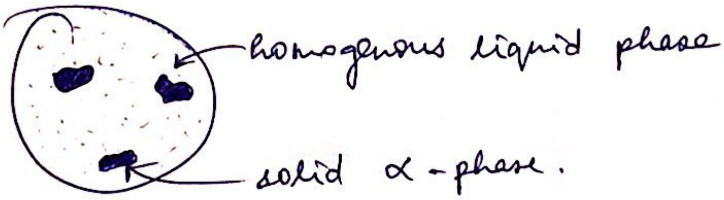
(ii). Initial phase field: L (liquid)

Final phase field: $\alpha+\beta$

Intermediate phase field: $L+\alpha$

(iii). L :

$L+\alpha$:



$\alpha+\beta$: (hypo-eutectic)