Question 1 [4+6+5]

1. (a) For a given material, would you expect the surface energy to be greater than, the same as, or less than the grain boundary energy? Why?

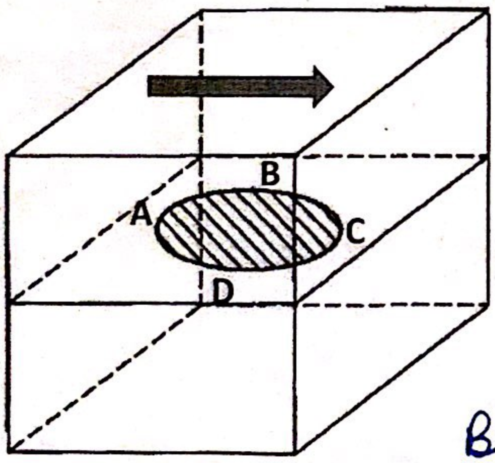
Surface energy for a given material will be greater than the grain boundary because coordination ~~no~~ number of atoms in grain boundary lies on average of 10 to 11 while surface ~~are~~ atoms have less than this coordination number. So, stabilising will be more in grain boundary than in surface energy. Hence energy is higher in surface than in grain boundary

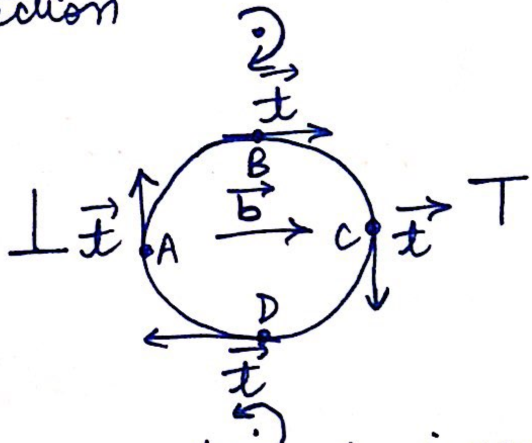
+2

+1

(b) The figure below shows an elliptical dislocation loop. If slip direction is from left to right (indicated by the arrow), provide a separate sketch of the plan view of the dislocation loop and show the dislocation line vector and Burgers vectors at points A, B, C and D. Identify the type of dislocation at each of these points.

→ slip direction





Burgers vector is invariant

At A ⇒ $\uparrow \vec{t}$, $\rightarrow \vec{b}$ Edge Dislocation (positive) $\perp$

+6

At B ⇒ $\xrightarrow{\vec{t}}$ $\xrightarrow{\vec{b}}$ Screw Dislocation (positive)

At C ⇒ $\rightarrow \vec{b}$, $\downarrow \vec{t}$ Edge Dislocation (negative) $\top$

At D ⇒ $\xrightarrow{\vec{b}}$ $\xleftarrow{\vec{t}}$ Screw Dislocation (negative)

(c) Calculate the fraction of atom sites that are vacant for lead at its melting temperature of 327°C (600 K). Assume an enthalpy for vacancy formation of 0.55 eV/atom.

$\because \underbrace{\frac{n}{N}}_{\text{fraction}} = e^{-\frac{\Delta H_v}{RT}}$

where ΔH_v = Enthapy of vacancy in J/mol.

$$\Delta H_v = \frac{0.55 \times 1.602 \times 10^{-19}}{\cancel{\text{atom}}} \times 6.022 \times 10^{23} \frac{J}{mol}$$

$$\Delta H_v = 5.306 \times 10^4 J/mol = 53.06 \text{ kJ/mol}$$

$$\text{fraction} = \frac{n}{N} = e^{-\left(\frac{53.06 \times 10^3}{8.314 \times 600}\right)}$$

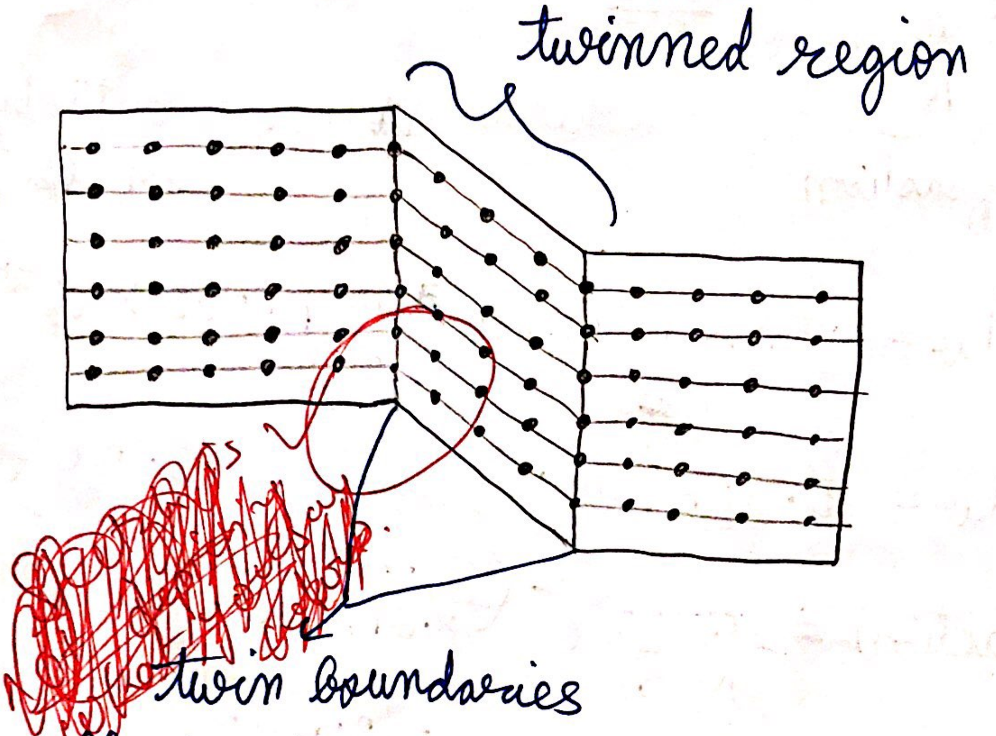
$$\text{fraction} = e^{-10.636}$$

$$\text{fraction of vacancies} = 2.403 \times 10^{-5}.$$

+5

Question 2 [5+5+5]

(a) Define crystal twinning and provide a neat sketch of a twinned crystal. Indicate twinned region and twin boundaries.



Twinned crystal

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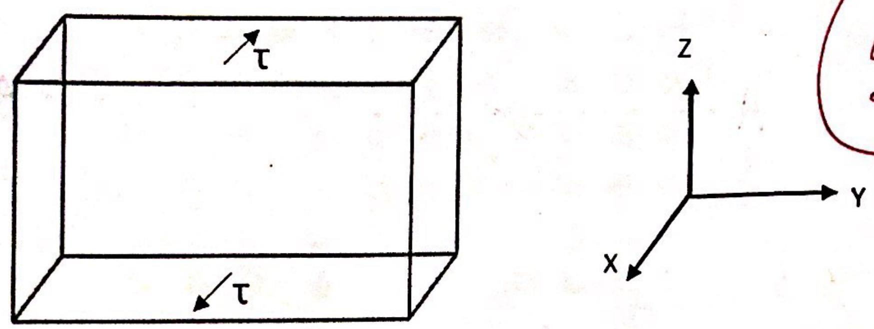
Twin boundaries reflect the mirror image in ~~of~~ the twinned part.

When stress applied deforms the crystal only in alignment to some part of crystal in a mirror image form then it is called crystal twinning.

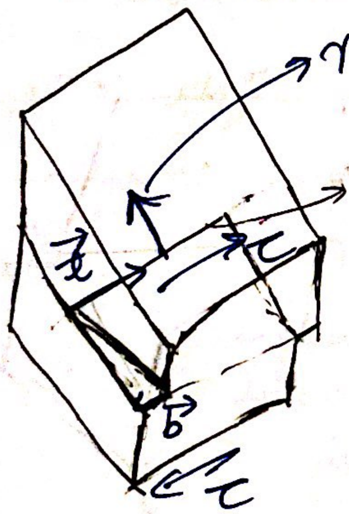
(b) Shear stress (τ) is being applied to a metal block as shown below. If the deformation is caused by the motion of a screw dislocation, sketch the orientation of the screw dislocation and its character when slip has occurred almost halfway through the crystal. Indicate the direction in which dislocation line would move for further slip to occur.

5



movement ~~of~~ of dislocation line in given direction if stress is increased.

dislocation line



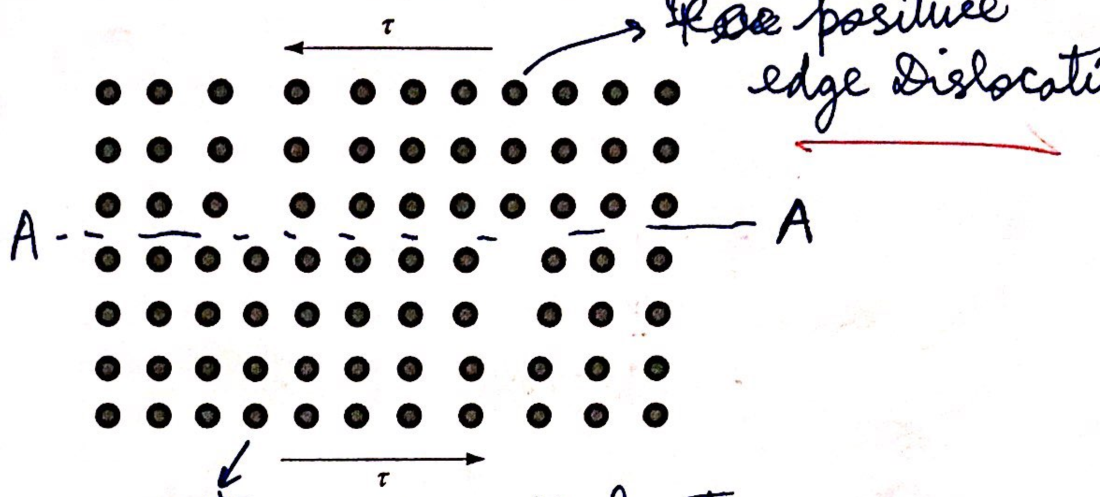
On keeping the stress

$\vec{b}$

$\vec{t}$ negative screw Dislocation

Direction of movement of dislocation line.

(c) Identify the defects in the crystal shown in Figure below. If a shear stress is applied to the crystal as shown, discuss what will happen to these defects? Show the resulting atomic configuration with a simple sketch.



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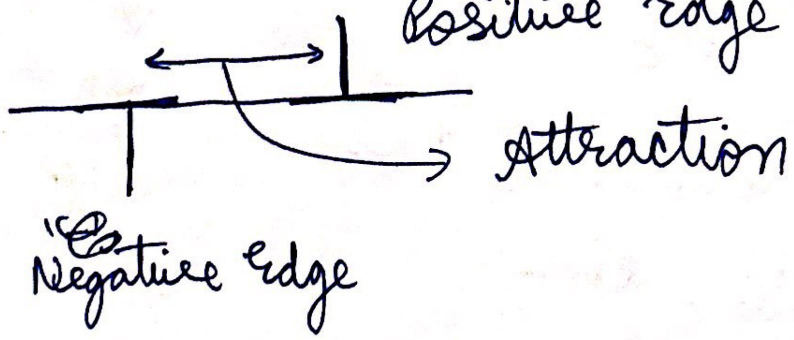
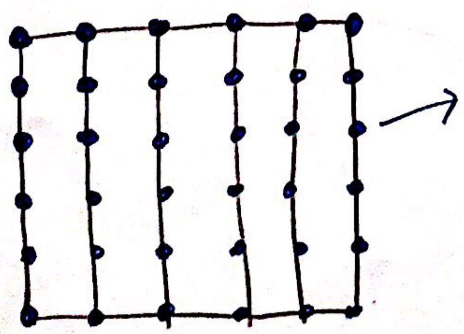
Since Negative Edge Dislocation will create compression field below A and Positive edge Dislocation will create tensile field below A plane So, these will combine to make a perfect Crystal with no ~~defects~~ Internal Defects.



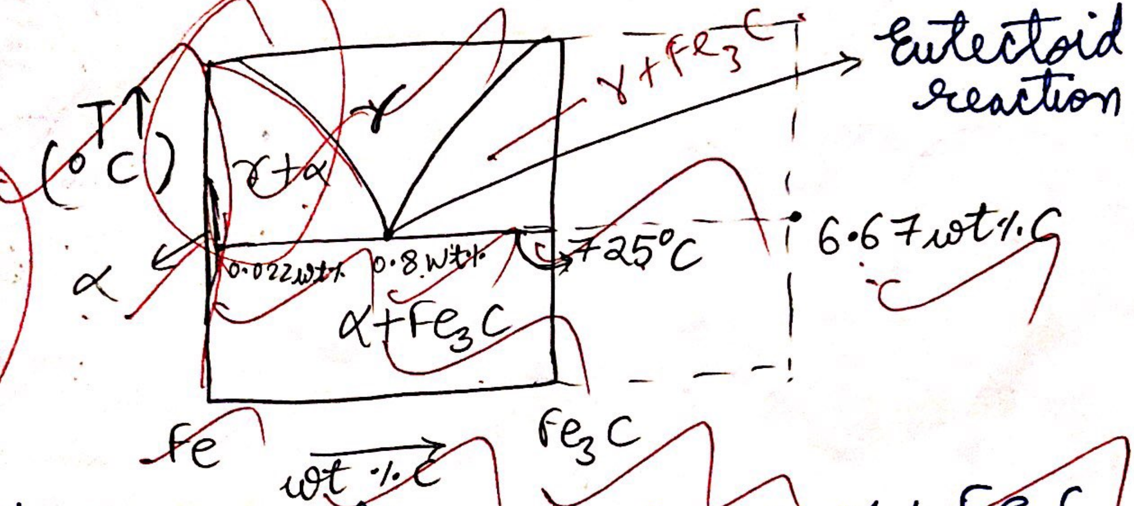


→ perfect crystal After applying Shear stress.

Question 3 **[9+6]**

(a) Neatly sketch part of the phase diagram showing eutectoid reaction in Fe-Fe_3C system and label all the phases. For eutectoid steel, compute the mass fractions of α ferrite and cementite in pearlite (given α ferrite has 0.022 wt% C).

6.5



Reaction on cooling ⇒ $\gamma \longrightarrow \alpha + Fe_3C$

α = Ferrite   γ = Austenite.

Eutectoid reaction takes place at 725°C and wt% of carbon is 0.8.

Using lever rule,

mass fractions:

$$f_\alpha \text{ in pearlite} = \frac{6.67 - 0.8}{6.67 - 0.022} = 0.883.$$

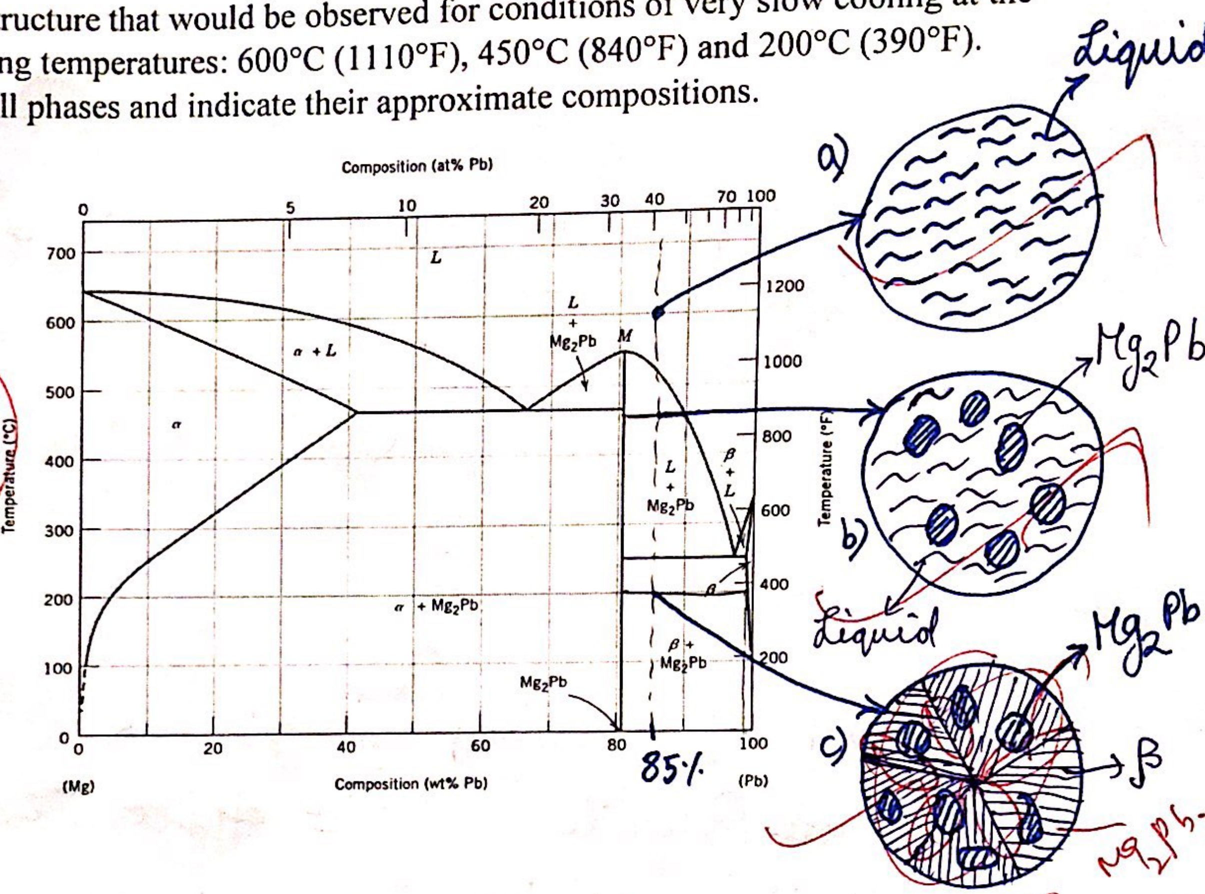
$$f_{Fe_3C} \text{ in pearlite} = 0.117.$$

2

Pearlite is not a phase it is mixture of Ferrite and Cementite.

(b) For an 85 wt% Pb-15 wt% Mg alloy, make schematic sketches of the microstructure that would be observed for conditions of very slow cooling at the following temperatures: 600°C (1110°F), 450°C (840°F) and 200°C (390°F). Label all phases and indicate their approximate compositions.

2.5



a) For Liquid the composition is 85% wt. Pb (15% wt Mg)

b) For liquid in (b). $f_{L(b)} = \frac{85-81}{90-81} = \frac{4}{9} = 0.44$

$f_{Mg_2Pb} = 0.56$.

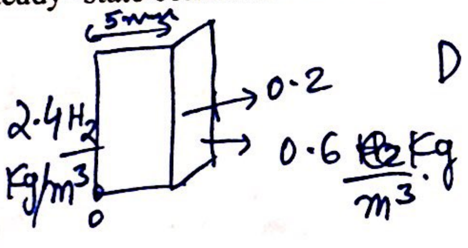
2

c) For β in (c) $f_{\beta} = \frac{85-81}{99-81} = 0.22$

$f_{Mg_2Pb} = 0.78$.

Question 4

(a) 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.



$D = 1 \times 10^{-8}$

At steady state.

$$\frac{dC}{dx} = A$$

$$\boxed{C_{H_2} = Ax + B}$$

$$C_{H_2} = \begin{cases} 2.4 & x = 0 \\ 0.6 & x = 5 \times 10^{-3} \end{cases}$$

$B = 2.4$

$5 \times 10^{-3} A = 0.6 - 2.4$

$A = \frac{-1.8}{5} \times 1000$

$A = -360.$

1

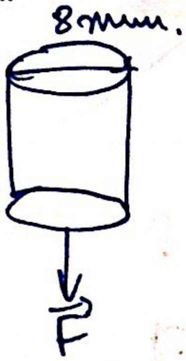
$C_{H_2} = 2.4 - 360x.$

$\frac{dn}{dt}$ $J = -DA\frac{dC}{dx} = -10^{-8} \times 0.2 \times (-360)$ Kg/hr.

Diffusion

$J = 7.2 \times 10^{-7}$ Kg/hr.

(b) A cylindrical specimen of some alloy 8 mm in diameter is stressed elastically in tension. A force of 15,700 N produces a reduction in specimen diameter of 5×10^{-3} mm. Compute Poisson's ratio for this material if its modulus of elasticity is 140 GPa.



$$\text{Stress} = \frac{F}{A} = \frac{15700 \times 4}{\pi D^2}$$

$$\text{stress} = \frac{15700 \times 4 \times 10^6}{\pi \times 64}$$

$$\text{Stress} = 3.123 \times 10^8.$$

$$\text{strain} = \frac{\text{stress}}{140 \times 10^9} = 2.23 \times 10^{-3}.$$

$$\text{Strain} = \frac{\Delta l}{l} = 2.23 \times 10^{-3}.$$

5

Poisson's ratio = ?