TURBO
Continuous change

اسئلة مقترحة :

علم المواد

Material Science

Ch4+6+7

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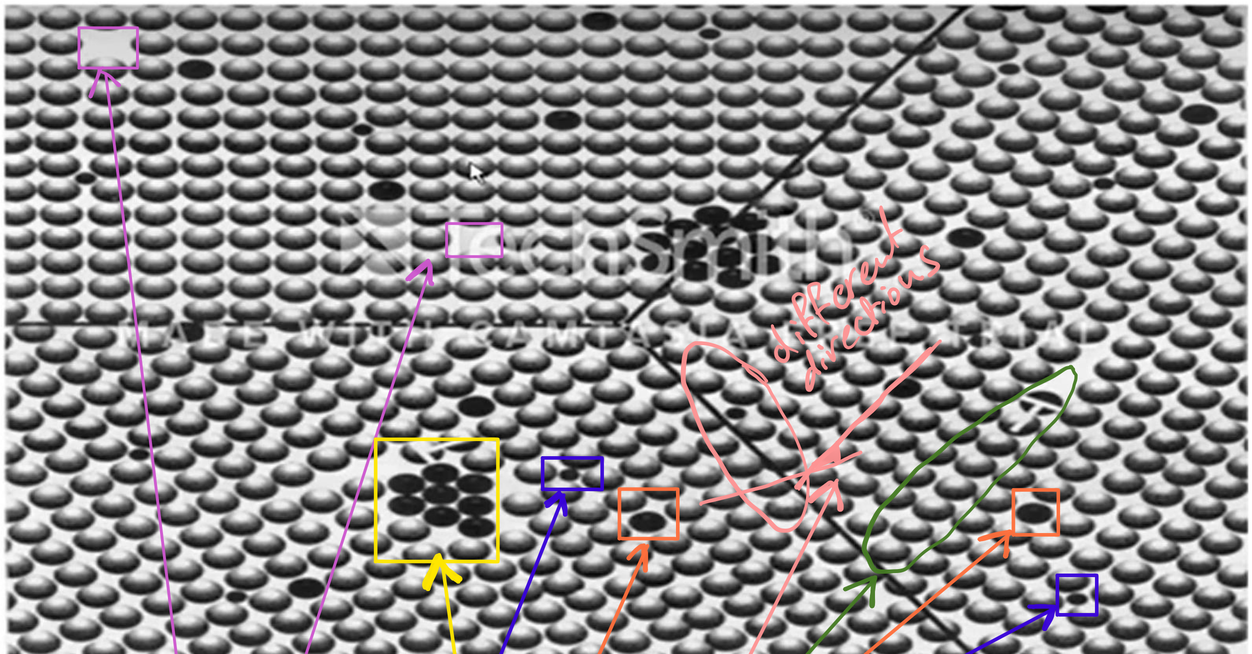
اللجنة الأكاديمية لقسم الهندسة الصناعية

2025

Suggested problems on CH 4 (Important)



Q1) Locate the following imperfection solid types ?

- Vacancy
- Interstitial point defect
- Substitutional point defect
- Line (edge) dislocation
- Grain boundaries defects
- Volume defects (foreign inclusions)

Q2) Below, atomic radius, crystal structure, electronegativity, and the most common valence are tabulated, for several elements; for those that are nonmetals, only atomic radii are indicated. Which of these elements would you expect to form the following with nickel:

(a) A substitutional solid solution having complete solubility

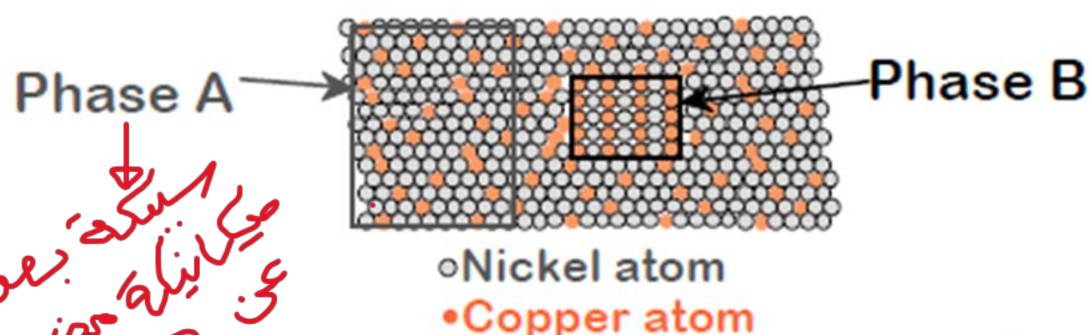
(b) A substitutional solid solution of incomplete solubility

(c) An interstitial solid solution

Element	*Atomic Radius (nm)*	*Crystal Structure*	*Electro-negativity*	*Valence*
Ni	0.1246	FCC	1.8	+2
C	0.071			
H	0.046			
O	0.060			
Ag	0.1445	FCC	1.9	+1
Al	0.1431	FCC	1.5	+3
Co	0.1253	HCP	1.8	+2
Cr	0.1249	BCC	1.6	+3
Fe	0.1241	BCC	1.8	+2
Pt	0.1387	FCC	2.2	+2
Zn	0.1332	HCP	1.6	+2

Solid Solutions

A solid solution forms when, as the solute atoms are added to the host material, the crystal structure is maintained, and no new structures are formed. Perhaps it is useful to draw an analogy with a liquid solution. If two liquids, soluble in each other (such as water and alcohol) are combined, a liquid solution is produced as the molecules intermix, and its composition is homogeneous throughout. **A solid solution is also compositionally homogeneous; the impurity atoms are randomly and uniformly dispersed within the solid** (alloy with constant properties every where (الصفات المطلوبة)



Impurity point defects are found in solid solutions, of which there are two types: **substitutional** and **interstitial.** For the substitutional type, solute or impurity atoms replace or substitute for the host atoms (Figure 4.2). There are several features of the solute and solvent atoms that determine the degree to which the former dissolves as follows:

1. *Atomic size factor*. Appreciable quantities of a solute may be accommodated in this type of solid solution only when the difference in atomic radii between the two atom types is less than about ±15%. Otherwise the solute atoms will create substantial lattice distortions and a new phase will form.
2. *Crystal structure*. For appreciable solid solubility the crystal structures for metals of both atom types must be the same.
3. *Electronegativity*. The more electropositive one element and the more electronegative the other, the greater is the likelihood that they will form an intermetallic compound instead of a substitutional solid solution.
4. *Valences*. Other factors being equal, a metal will have more of a tendency to dissolve another metal of higher valency than one of a lower valency.

An example of a substitutional solid solution is found for copper and nickel. These two elements are **completely soluble** in one another at all proportions. With regard to the aforementioned rules that govern degree of solubility, the atomic radii for copper and nickel are 0.128 and 0.125 nm, respectively, both have the FCC crystal structure, and their electronegativities are 1.9 and 1.8 (Figure 2.7); finally, the most common valences are for copper +1 or +2 in some cases and for nickel +2.

For interstitial solid solutions, impurity atoms fill the voids.. For metallic materials that have relatively high atomic packing factors, these interstitial positions are relatively small. the atomic **diameter of an interstitial impurity must be substantially smaller** than that of the host atoms.

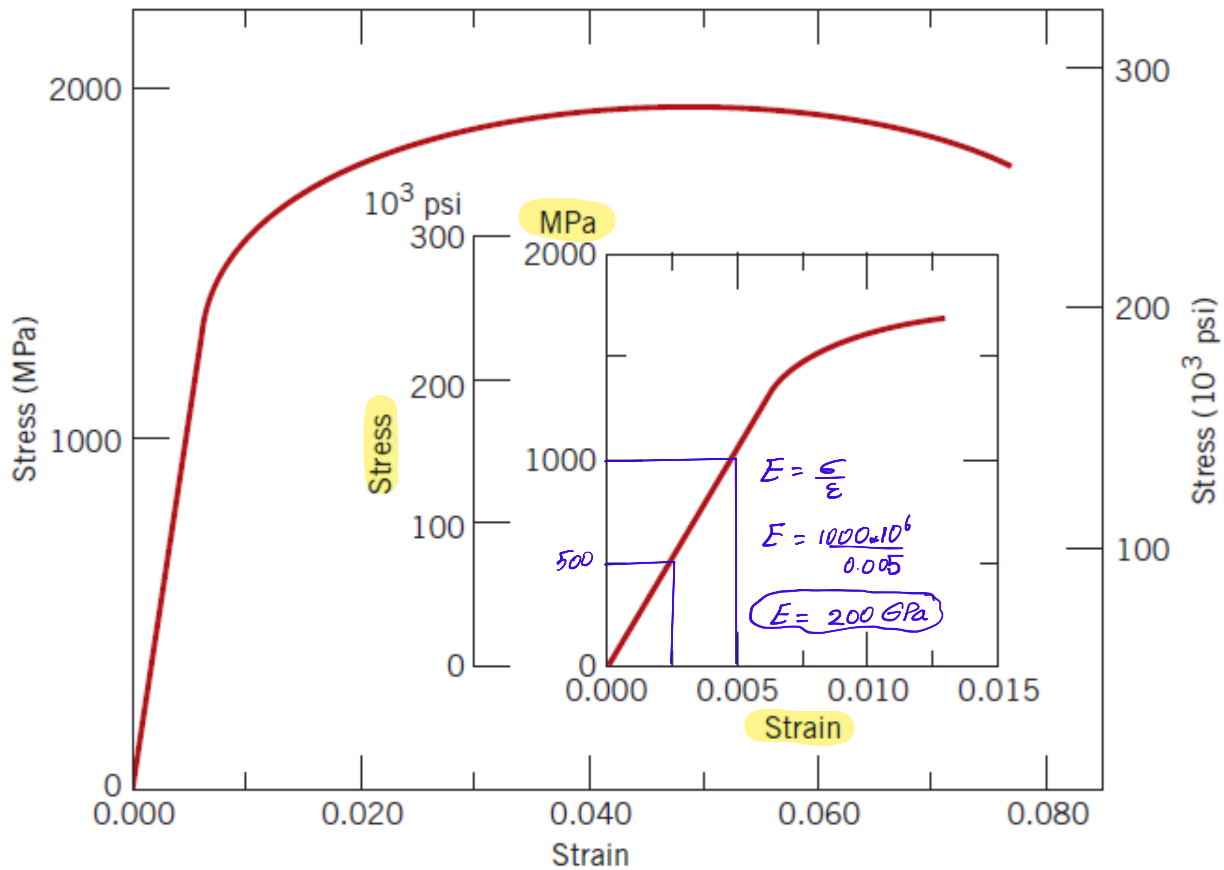
Carbon forms an interstitial solid solution when added to iron; the maximum concentration of carbon is about 2%. The **atomic radius of the carbon atom is much less** than that for iron: 0.071 nm versus 0.124 nm

$d = 8.5 * 10^{-3} m$

$l_0 = 80 \times 10^{-3} m$

6.9: Consider a cylindrical specimen of a steel alloy (Figure 6.21) 8.5 mm (0.33 in.) in diameter and 80 mm (3.15 in.) long that is pulled in tension. Determine its elongation when a load of 65,250 N (14,500 lb) is applied.

$F =$ $\Delta L = ?$



$$\sigma = \frac{F}{A}$$

$$\sigma = \frac{65.25}{\left(\frac{8.5 * 10^{-3}}{2}\right)^2 3.14}$$

$$\boxed{\sigma = 1.15 \text{ MPa}}$$

$$\varepsilon = \frac{\Delta L}{L_o}$$

$$\frac{\sigma}{E} = \frac{\Delta L}{L_o}$$

$$\Delta L = \frac{L_o \sigma}{E}$$

$$= \frac{(80 * 10^{-3})(1.15 * 10^6)}{200 * 10^9}$$

$$\Delta L = 4.6 * 10^{-7} m$$

$$\boxed{\Delta L = 4.6 * 10^{-4} mm}$$

6.18 Consider a cylindrical specimen of some hypothetical metal alloy that has a diameter of 10.0 mm (0.39 in.). A tensile force of 1500 N (340 lb_f) produces an elastic reduction in diameter of 6.7×10^{-4} mm (2.64×10^{-5} in.). Compute the elastic modulus of this alloy, given that Poisson's ratio is 0.35.

6.23 A cylindrical rod 500 mm (20.0 in.) long, having a diameter of 12.7 mm (0.50 in.), is to be subjected to a tensile load. If the rod is to experience neither plastic deformation nor an elongation of more than 1.3 mm (0.05 in.) when the applied load is 29,000 N (6500 lb_f), which of the four metals or alloys listed below are possible candidates? Justify your choice(s).

Material	*Modulus of Elasticity (GPa)*	*Yield Strength (MPa)*	*Tensile Strength (MPa)*
Aluminum alloy	70	255	420
Brass alloy	100	345	420
Copper	110	210	275
Steel alloy	207	450	550

6.40 For a brass alloy, the following engineering stresses produce the corresponding plastic engineering strains, prior to necking:

Engineering Stress (MPa)	*Engineering Strain*
315	0.105
340	0.220

On the basis of this information, compute the *engineering* stress necessary to produce an *engineering* strain of 0.28.

$E = \frac{\sigma}{\varepsilon}$

$\frac{340-315}{0.220-0.105} = \frac{340-x}{0.22-0.28}$

$x = \square$

6.46 (a) A 10-mm-diameter Brinell hardness indenter produced an indentation 2.50 mm in diameter in a steel alloy when a load of 1000 kg was used. Compute the HB of this material.

(b) What will be the diameter of an indentation to yield a hardness of 300 HB when a 500-kg load is used?

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d= F

means negative.

$d_0 = 0.01 m$

$F = 1500 N$

$E = ?$

$\Delta d = -6.7 * 10^{-7} m$

$\nu = 0.35$

$\sigma_x = \frac{F}{A} = \frac{1500 (4)}{(0.01)^2\ 3.14} = 19 * 10^6 Pa = 19\ MPa.$

$\varepsilon_y = \frac{\Delta d}{d_0} = \frac{-6.7 * 10^{-7}}{0.01} = 67 * 10^{-6}$

$\nu = - \frac{\varepsilon_y}{\varepsilon_x} \Rightarrow 0.35 = - \frac{-67\ 10^{-6}}{\varepsilon_x}$

$\varepsilon_x = \frac{67 * 10^{-6}}{0.35} = 191.4 * 10^{-6}$

$E = \frac{\sigma_x}{\varepsilon_x} = \frac{19 * 10^6}{191.4 * 10^{-6}} = 9.92 * 10^{10} = 99.2 * 10^9 = 99.2\ GPa$

6.46 **(a)** A 10-mm-diameter Brinell hardness indenter produced an indentation 2.50 mm in diameter in a steel alloy when a load of 1000 kg was used. Compute the HB of this material.

(b) What will be the diameter of an indentation to yield a hardness of 300 HB when a 500-kg load is used?

a.

$D = 10 mm$

$d = 2.5 mm$

$F = P = 1000 kg$

$HB\ ?$

$HB = \frac{2P}{\pi D [D - \sqrt{D^2 - d^2}]}$

$HB = 200.5$

b.

$d = ?$

$HB = 300$

$P = 500$

$d = \sqrt{D^2 - \left(D - \frac{2P}{\pi D\ HB}\right)^2}$

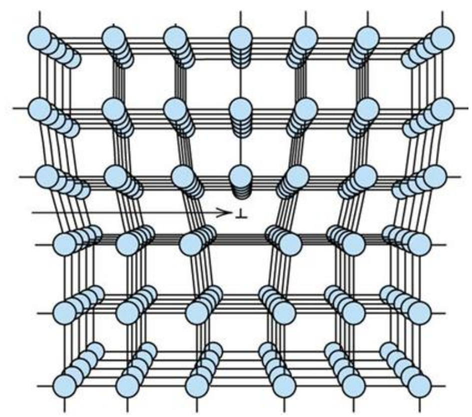
$d = 1.45$

7.24 The lower yield point for an iron that has an average grain diameter of 1×10^{-2} mm is 230 MPa (33,000 psi). At a grain diameter of 6×10^{-3} mm, the yield point increases to 275 MPa (40,000 psi). At what grain diameter will the lower yield point be 310 MPa (45,000 psi)?

7.26 In the manner of Figures 7.17*b* and 7.18*b*, indicate the location in the vicinity of an edge dislocation at which an interstitial impurity atom would be expected to be situated. Now briefly explain in terms of lattice strains why it would be situated at this position.

Answer:-

The interstitial impurity atom would be expected to be located below the edge dislocation line, where there is tensile strain. This is because the lattice is stretched in this region, providing more space for the smaller interstitial atom, thus minimizing the elastic strain energy.



7.27 **(a)** Show, for a tensile test, that

$$\%\,CW = \left(\frac{\epsilon}{\epsilon + 1}\right) \times 100$$

if there is no change in specimen volume during the deformation process (i.e., $A_0 l_0 = A_d l_d$).

(b) Using the result of part (a), compute the percent cold work experienced by naval brass (for which the stress–strain behavior is shown in Figure 6.12) when a stress of 415 MPa (60,000 psi) is applied.

من المنحنى البياني بنلاقي $\epsilon = 0.22$ → وبنعوض بالمعادلة فوق.

$CW\% = 18\%$

Question: Briefly explain why small-angle grain boundaries are not as effective in interfering with the slip process as are high-angle grain boundaries.

Answer:

Small-angle grain boundaries consist of low misorientation and ordered dislocation arrays, offering less obstruction to dislocation movement. In contrast, high-angle grain boundaries present significant misorientation and disrupt the slip process more effectively, thereby strengthening the material.

7.24 The lower yield point for an iron that has an average grain diameter of 1×10^{-2} mm is 230 MPa (33,000 psi). At a grain diameter of 6×10^{-3} mm, the yield point increases to 275 MPa (40,000 psi). At what grain diameter will the lower yield point be 310 MPa (45,000 psi)?

$$\sigma_y = \sigma_0 + k d^{-1/2}$$

σ_y: MPa مقاومة الخضوع

σ_0: MPa مقاومة الخضوع النظرية

k: ثابت مواد

d: القطر

$\sigma_{0_1} = \sigma_{0_2}$
k constant

- $230 = \sigma_0 + \dfrac{k}{\sqrt{0.01}}$

حذف وتعويض

- $275 = \sigma_0 + \dfrac{k}{\sqrt{6 \times 10^{-3}}}$

المطلوب

- $310 = \sigma_0 + \dfrac{k}{\sqrt{d}}$ ← ؟

$(230 - \sigma_0)\sqrt{0.01} = k$ --> 1

$(275 - \sigma_0)\sqrt{6 \times 10^{-3}} = k$ --> 2

أو هون نساوي حسابا للأطراف مع k
نعوض ثم نطلع σ_0
ونرجع نعوضها بأحد المعادلات

I cal $\sigma_y = 310$ → $d = 4.35 \times 10^{-3}$ mm

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Faculty of Engineering

Material Science Course

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Serial Number:......................... **Date:** ....

Problem 1: Multiple choice Questions :

1. During Plastic deformation in metallic alloys is the result of :

A) Necking B) Bond Breaking C) Bond stretching D) Dislocation motion

E) All of the above

2. During elastic deformation, a metal experiences:

A) Necking B) Bond stretching C) Bond Breaking D) All of the above

E) None of the above

3. Resistance to plastic deformation is termed:

A) Modulus of elasticity

B) Toughness

C) Yield Strength

D) Hardness

E) Ductility

4) Material with lowest toughness :

A) Have greatest ductility

B) have greatest modulus of elasticity

C) Have combination of high strength and high ductility

D) Have combination of low strength and low ductility

Or percent reduction.

5) The percent elongation of a material at fracture measures its:

A) fracture strength

B) Ultimate strength

C) Toughness

D) Ductility

E) None of the above

6) What statement is incorrect regrading Edge and screw dislocation ?

A) magnitude of their Burger vector is equal

B) Only shear stress field exists in either case → shear & Normal → edge; only shear → screw

C) Burger vector is perpendicular to the dislocation line in edge dislocation

D) Burger vector is parallel to the dislocation line in screw dislocation

7) Substitutional defect:

A) comes from impurity atoms on lattice sites

B) are usually associated with vacant lattice sites

C) are found between along borders of crystal structures of different orientations

D) comes when one atom is replaced by a different type of atom

8) Carbon -Iron alloy is a system at which carbon atom (solute) interacts with iron as:

A) interstitial defect

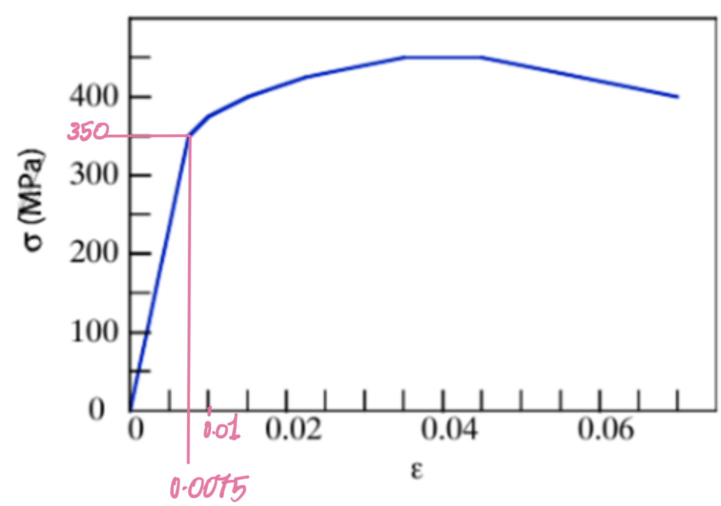
B) substitution defect

C) Vacancy defect

D) edge dislocation

9) The data on the right-hand side Figure could have been obtained from (1pt):

A) Brinell Hardness test
B) Shear Test
C) Impact test
D) Tensile test



10) **The data revealed that this sample had a Yield strength of: (1pt)**

A) 300 B) 350 C) 400 D) 450

11) **Dislocations began to move in the sample when the strain exceeds : (1pt)**

A) 0.0075 B) 0.0375 C) 0.0475 D) 0.02

12) Find the number of vacancies per cubic meter in gold at 700 °C. the energy for vacancy formation is 0.98 eV/atom. The density and atomic weight for gold are 18.6 gm/cm³ and 197 gm/mole, respectively. (k=8.62x10⁻⁵ eV/atom).

$$N_v = N\,exp\left(\frac{-Q_v}{kT}\right), \quad N = 6.022x10^{23}\frac{\rho}{A}$$

A) $3.5x10^{22}$ B) $3.5x10^{24}$ C) $4.8x10^{23}$ D) $4.8x10^{22}$

13) Below, atomic radius, crystal structure, electronegativity, and the most common valence are tabulated, for several elements; for those that are nonmetals, only atomic radii are indicated. Which of these elements would you expect to form **substitutional solid solution** having complete solubility with Nickel. **Discuss your answer**

Element	*Atomic Radius (nm)*	*Crystal Structure*	*Electro-negativity*	*Valence*
Ni	0.1246	FCC	1.8	+2
C	0.071			
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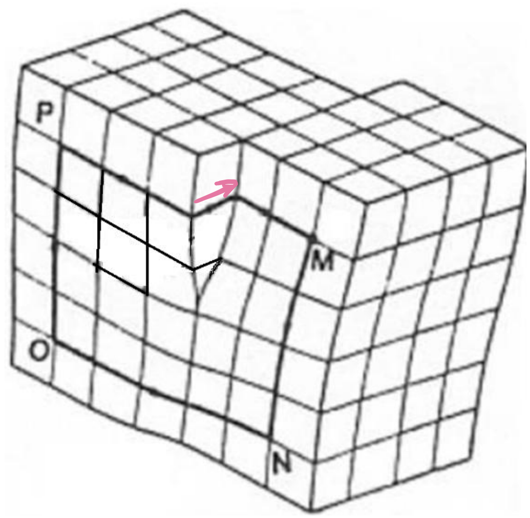
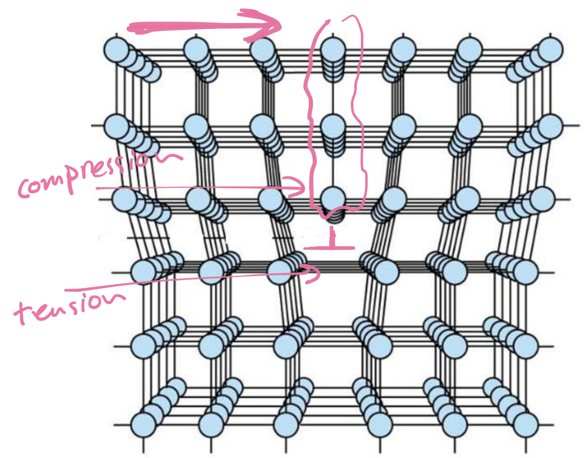
Fe	0.1241	BCC	1.8	+2
Pt	0.1387	FCC	2.2	+2
Zn	0.1332	HCP	1.6	+2

Problem 2 (4 pts): For the crystal shown below in (a), and (b). having a common type of solid imperfection or defect?



(a)



(b)

1) this line defect shown in **Figure a** is called ...Screw... dislocation
2) Show the Burger vector in **Figure (a)**, both magnitude and direction
3) This particular defect in **Figure (b)** is called ...Edge... dislocation
4) Show the Burger vector in **Figure (b),** both magnitude and direction

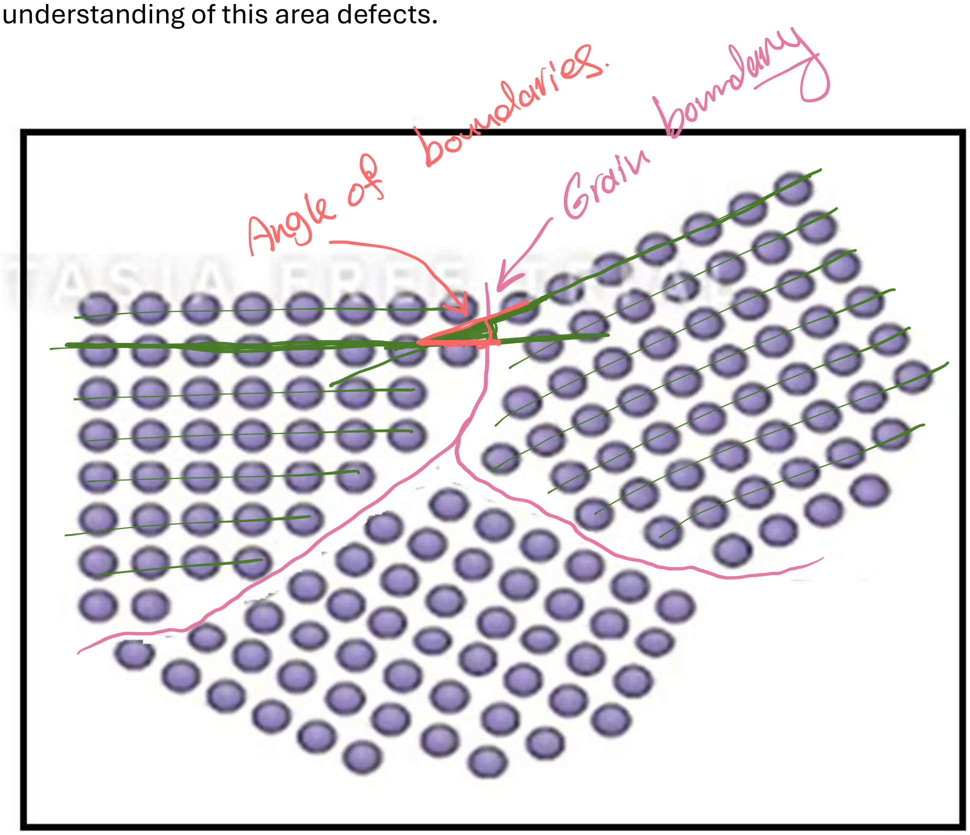
Problem 3 **(3 pts)**:

In your own words, describe briefly the difference between the following point defect:

- Interstitial point defect An extra atom is inserted into the spaces between lattice atoms.
- Substitutional point defect: lattice atom is replaced by a different type of atom."

<u>Good Luck</u>

A sketch for a the crystal structure of some polycrystalline metal. Based on definition of grain boundary region. Locate or draw the grain boundaries on the sketch below based on our understanding of this area defects.



Just ! like this.