Department of Materials Science and Engineering
HSSEAS
University of California, Los Angeles

MSE 104
Summer 2022
Prof. M.S. Goorsky

Midterm (1:50:00)

NAME: ________________________________ UID_________________

Problem 1_________(25)

Problem 2_________(10)

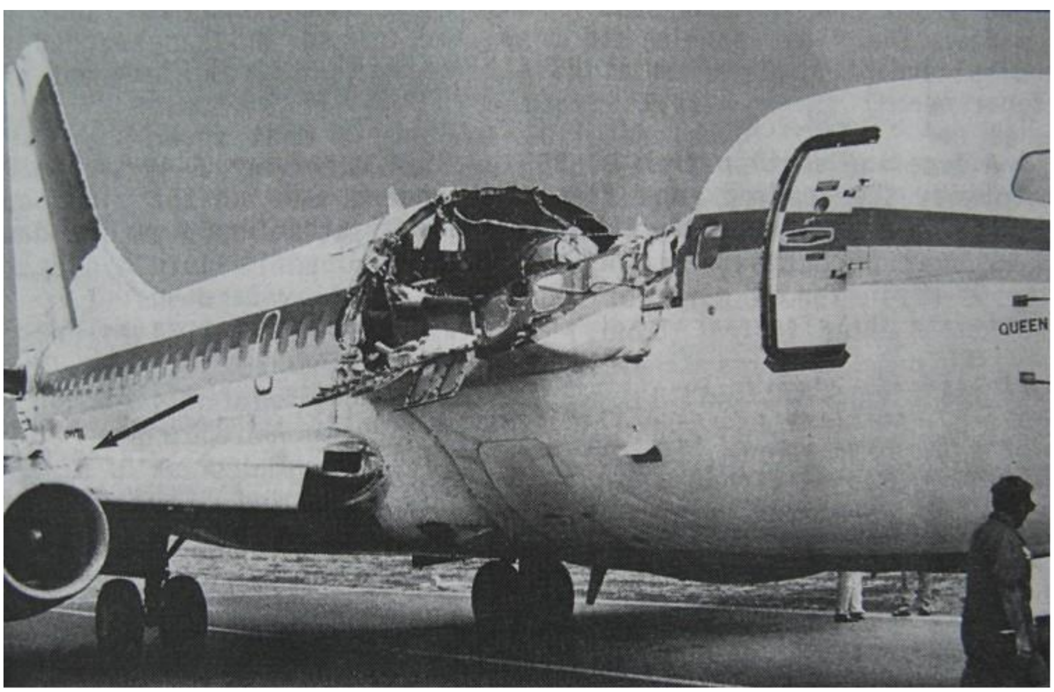
Problem 3_________(15)

Problem 4_________(15)

Problem 5_________(15)

Problem 6_________(20)

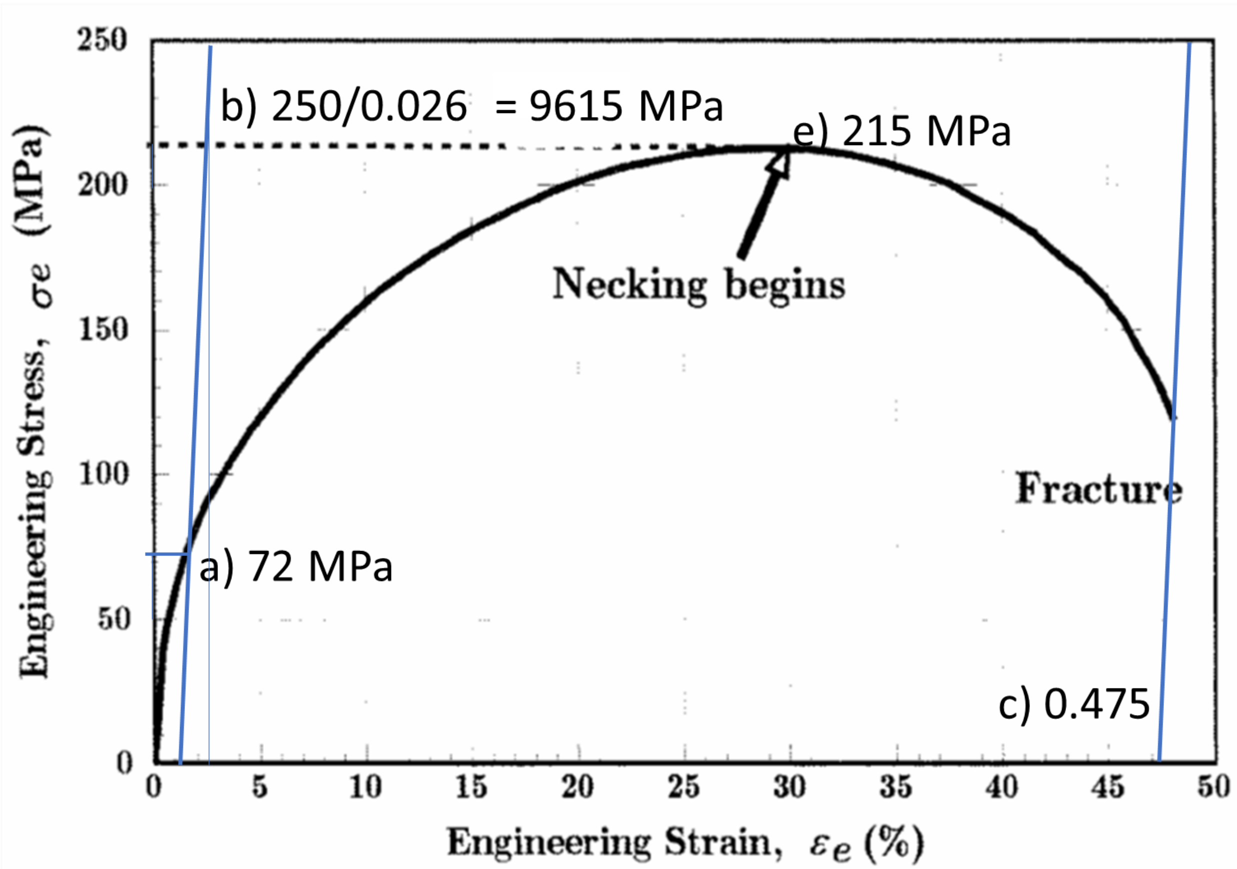
Total ___________(100)

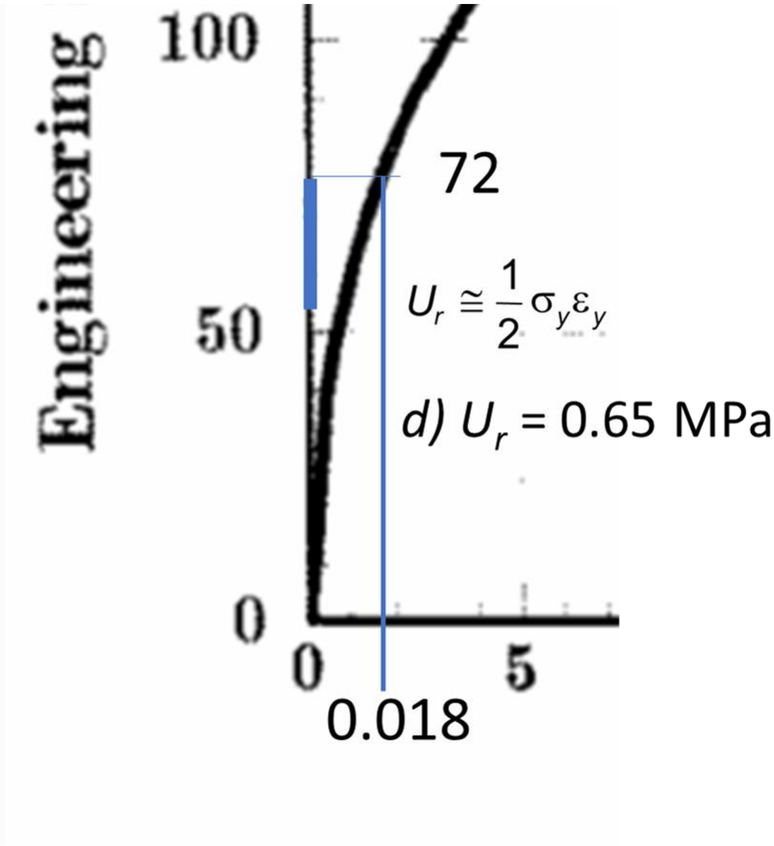


Problem 1 (25 points)

Identify the key points on the stress-strain curve and QUANTIFY each value (these will obviously just be approximations but show your reasoning for which values you chose using the graph below) (5 pts each). The graph is reproduced to make it easier to clearly shows your answers for the different parts.

a) Yield strength (use 1% strain rather than the standard 0.2% strain criterion):
b) Young's Modulus:
c) Ductility:
d) Resiliance:
e) Tensile Strength




Engineering
100
50
0
0
5
72
0.018
$U_r \cong \frac{1}{2}\sigma_y\varepsilon_y$
d) U_r = 0.65 MPa

<u>Problem 2 (10 points)</u> Mark your answers to the following questions, for multiple choice, there may be more than one correct answer:

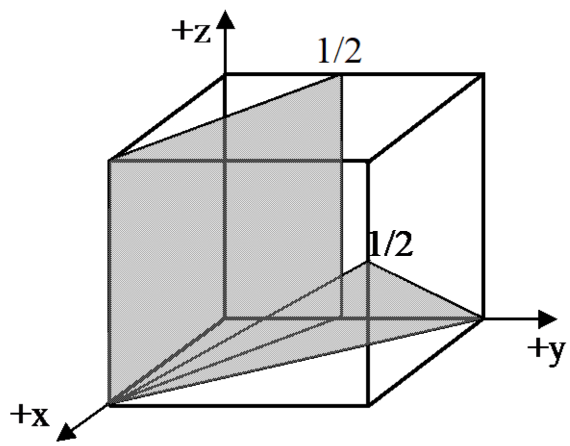
(2) Covalent bonding is a result of:

a. diffusion
b. exchange or transfer of electrons
c. ***sharing of electrons***
d. dislocation-solute atom interaction

(2) Creep refers to:

a. impact energy being significantly less at low temperatures than at high temperatures
b. ***a phenomenon which occurs at elevated temperatures (> 0.4T_m)***
c. failure under applied cyclic stress
d. a professor who schedules a midterm one week after a quiz

(3) Determine the Miller indices for the planes shown in the unit cell below.

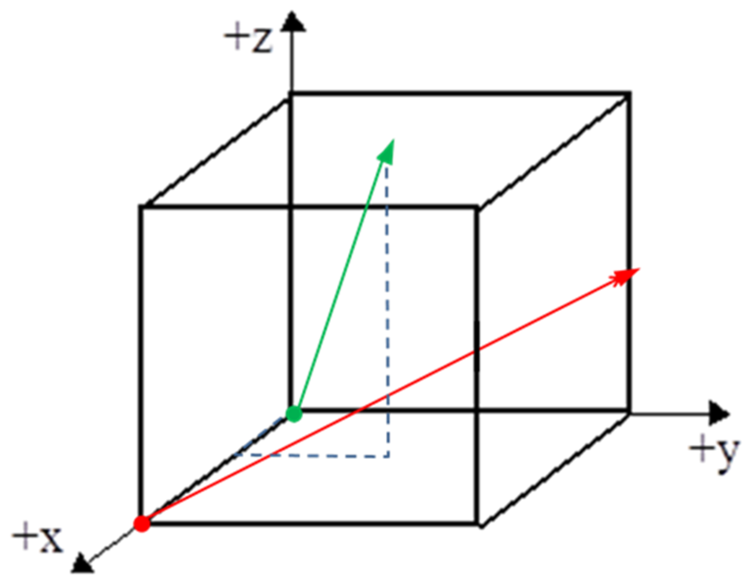


For the triangular-shaped plane, move the origin to the lower front right corner
The intercepts are at -1, -1, and ½ so the plane is:

$(\underline{1}\ \underline{1}\ 2)$

For the rectangular shaped plane, the origin can remain at the lower, back, left. The intercepts are 1, ½, ∞. Therefore, the plane is (1 2 0).

(3) Within the cubic unit cell shown below sketch directions $[\bar{2}21]$ and $[112]$.


+z
+y
+x

$$\exp\left[\frac{-0.059}{8.62\cdot 10^{-5}\cdot(353)}\right]\cdot 49 = 7.049$$

Problem 3 (15 points)

a) The 44 students in MSE 104 arrange themselves in the classroom (49 chairs) in a square two dimensional lattice. Draw this arrangement. A chair (lattice site) without a student is a vacancy.

x	x	x	x	o	x	x
x	x	o	x	x	x	x
x	x	x	x	x	x	x
x	x	x	x	x	x	x
o	x	x	x	x	o	x
x	x	o	x	x	x	x
x	x	x	x	x	x	x

b) What is the student vacancy activation energy?

$$\frac{N_V}{N_S} = exp\left(\frac{-E_A}{k_B T}\right)$$
$$\frac{5}{49} = exp\left(\frac{-E_A}{8.62\cdot 10^{-5}\cdot 298}\right)$$

$E_A = 0.059$ eV

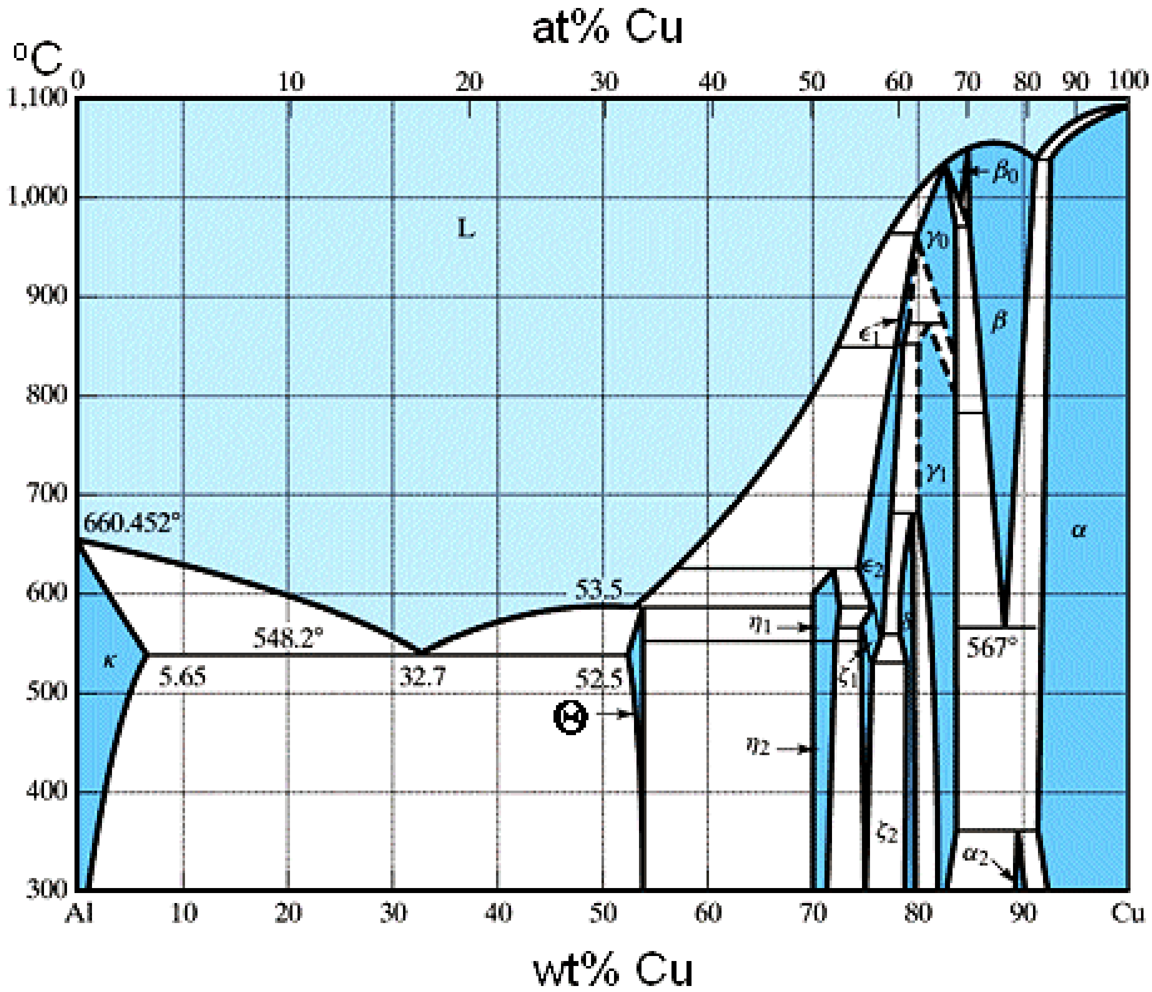
c) What would the vacancy fraction be if the room were heated to 80 °C? **7 vacancies or 14.3%**

$$\exp\left[\frac{-0.059}{8.62\cdot 10^{-5}\cdot(353)}\right]\cdot 49 = 7.049$$

d) How are vacancies created at increasing temperatures?

Vacancies are created as atoms diffuse onto the existing surface of the material – in other words by adding to and building surface planes / terraces at the edges of such terraces

Problem 4 (15 points)



The Al-Cu phase diagram is shown above. Consider two compositions that have less than 80 wt % Cu:

i) 3 wt% Cu

ii) Eutectic

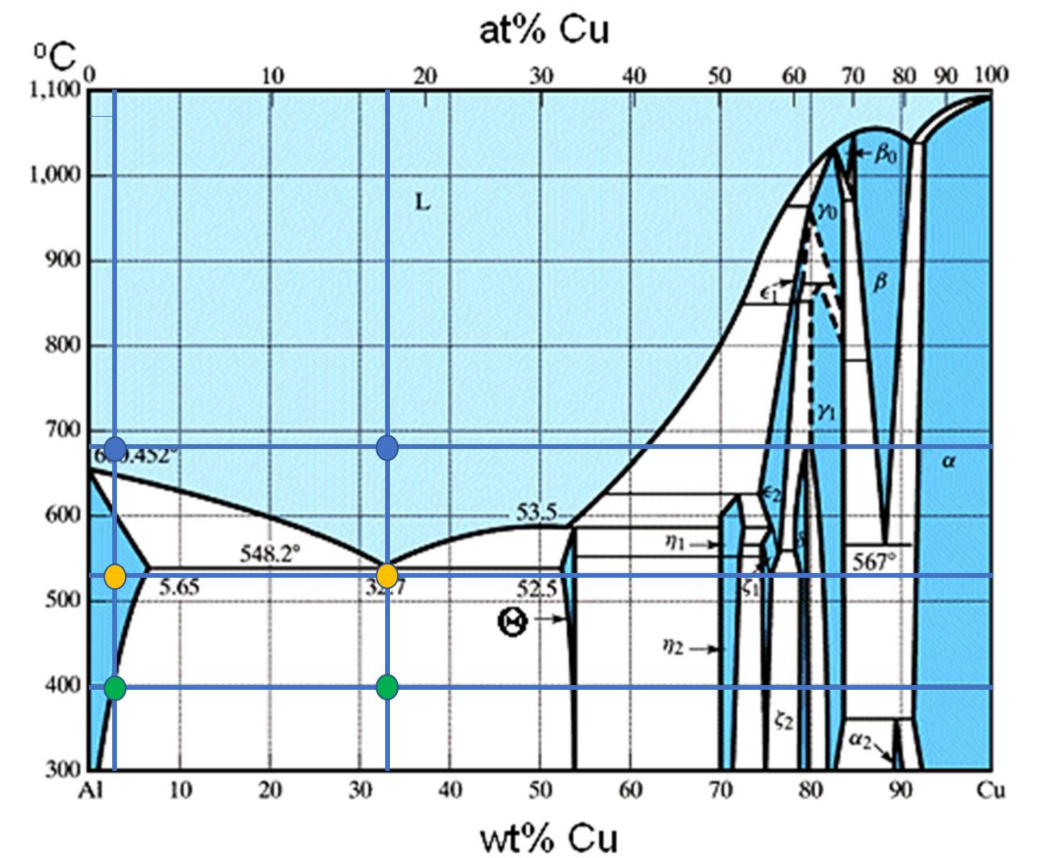
For each, answer the following:

Which phases (and their compositions) are present at equilibrium?

a) 670 °C

b) 540 °C

c) 400 °C



ia) 3 wt% Cu at 670 °C: This composition is above the melting point so the only phase is liquid with a composition of 3 wt% Cu

iib) eutectic at 670 °C. Liquid with composition 32.7 w% Cu

ib) 3 wt% Cu at 540 °C: This composition is in the single phase field κ so only κ (Al with a small amount of Cu dissolved) is resent with a composition of 3 w% Cu

iib) eutectic at 540 °C. This is just below the eutectic temperature (548.2 °C) so both κ and Θ phases are present. One can use the tie line concentrations at the eutectic or modify for the slight difference in temperature.

The κ phase is 5.65 w% Cu (Al with some Cu dissolved). The Θ phase is the compound $CuAl_2$ which is 52.5w% (or 33at%)Cu.

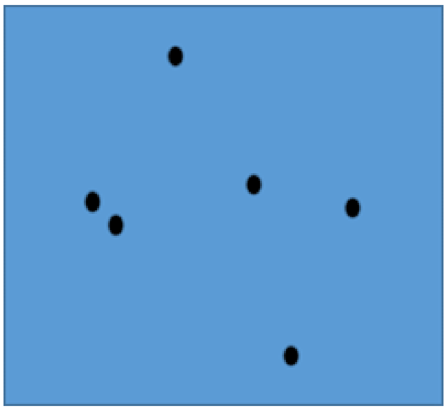
[The amount of each phase was not requested but there is about 42% κ and 58% Θ.]

iiia) 3 wt% Cu at 400 °C. Here, the average composition is just inside the κ+ Θ the phase region. The solubility of Cu in Al is 2.3 w% so κ is 2.3 w% Cu and Θ ($CuAl_2$) is 53 wt% Cu (or 33.3 at%). [Note – if you determined a slightly different value for the solubility at 400 °C, full credit was given]. [The amount of each phase was not requested but it is 98.6 w% Θ]

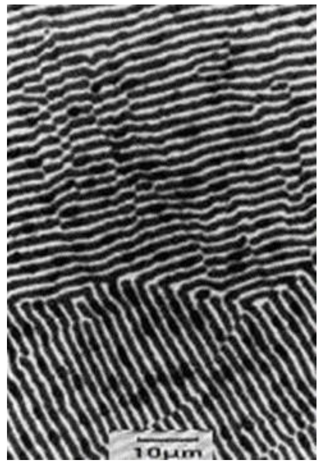
iiib) Eutectic at 400 °C. Here, the same two phases are present but the Cu content of each phase is slightly different than at 540 °C. κ is 2.3 w% Cu and Θ is 54 w% Cu.

[The amount of each phase was not requested but there is about 41% κ and 59% Θ.]

For (c) , sketch the microstructure in each case (3% Cu and the eutectic composition)



3%



Eutecetic

For the 3% case, the blue field represents the κ phase and the black dots the small amount of Θ that forms.   Even without a quantitative assessment, it is clear from the average composition on the phase diagram that there is little Θ present. The eutectic weight fraction phases are ~ 40-60.

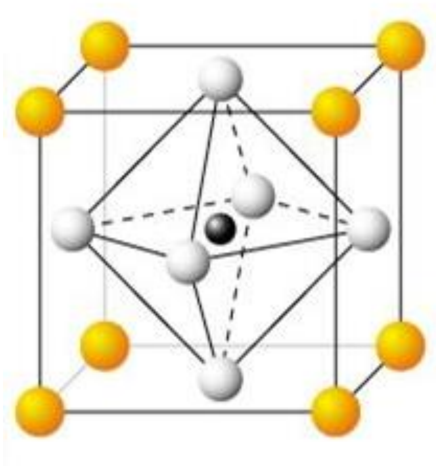
d) What are the chemical compositions of the Θ, η_2, and ζ_2 phases?
Using the at% scale at the top of the graph:
Θ is 33 at% Cu so Θ = $CuAl_2$

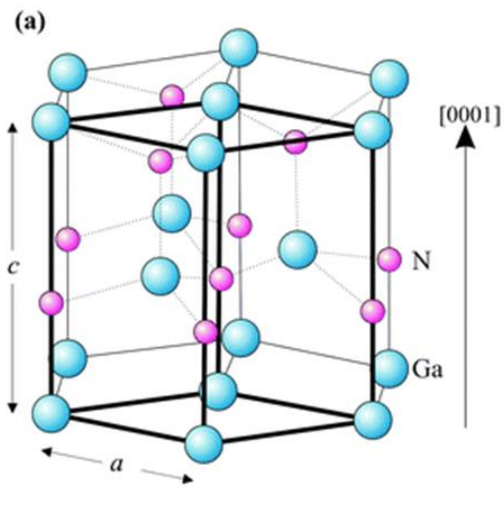
η_2 = *CuAl*

ζ_2 = *Cu_3Al_2*

Problem 5 (15 points)

(3 each) a. Identify the Bravais lattices below and determine the chemical formula for each crystal structure:





Structure ***Simple cubic***

Formula:***Ye(Yellow)B black)Wh$_3$ (white)***

Structure ***Hexagonal (but not close-packed***)

Formula: ***BlPi (Or GaN as given in the image.)***

(3) DBTT is an acronym for ***Ductile to Brittle Transition Temperature***.

b) (6) An Aloha Airlines airplane (on the first test page) made several flights each day (flight time ~ 45 minutes) between Honolulu and Hilo.

The fuselage likely failed due to ***fatigue***.

Explain in 1-2 sentences: ***Frequent short flights meant the cabin was pressurized and de-pressurized regularly, producing a cyclic stress on the fuselage.***

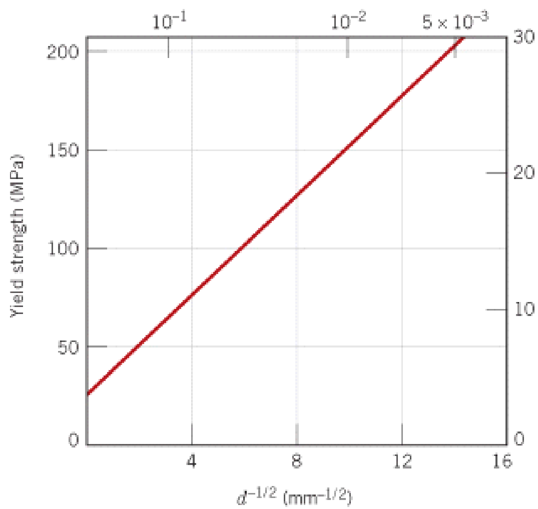
Problem 6 (15 points)

(5 each) The following graphs represent a certain means to strengthen materials

In the space to the right of each graph, identify the strengthening mechanism and provide a 1-2 sentence description of how to achieve the desired state

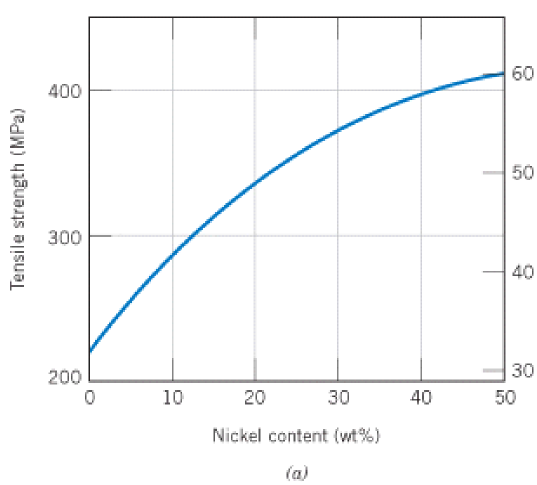
In the space to the right of each graph, identify the strengthening mechanism and provide a 1-2 sentence description of how to achieve the desired state

a)



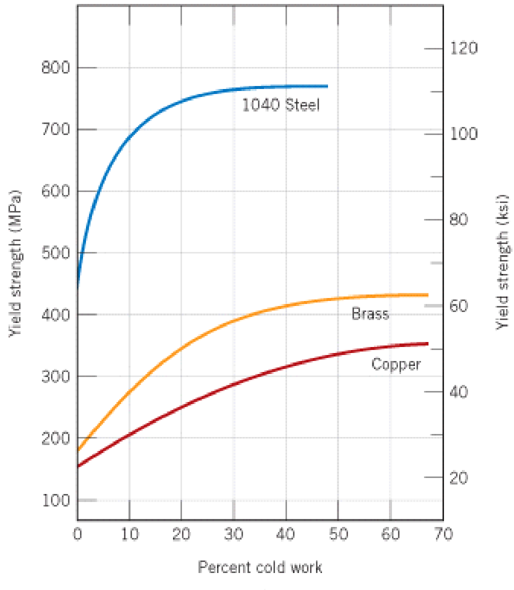
This is an example of strengthening by grain size reduction. As the grain size decreases, the yield strength increases as the grain boundaries provide barriers to the motion of the dislocations.

b)



This is solid solution hardening. Even the small size difference between Cu and Ni provides an impediment to dislocation mobility.

c)



Cold working increases the dislocation content such that it becomes difficult for dislocations to move past each other. The added dislocations provide an impediment to the movement of other dislocations.

Useful Constants:

N_A= 6.023 × 10^{23} molecules/mol

k = 1.38 × 10^{-23} J/atom-K = 8.62 × 10^{-5} eV/atom-K

R = 8.31 J/mol-K