ME 254
MATERIALS ENGINEERING
1st Semester 1434/1435
2nd Mid-Term Exam
(2 hrs)

Name: **No.:**

Question 1 (7 marks)

a) Briefly explain the difference between self-diffusion and interdiffusion. **(2 marks)**

b) Write Fick's first law in equation form, and define all parameters. **(2 marks)**

c) A sheet of steel 1.5 mm thick has nitrogen on both sides at 1200 °C and achieved steady state diffusion. The diffusion coefficient of nitrogen in steel at this temperature is 6×10^{-11} m^2/s, and the diffusion flux is found to be 1.2×10^{-7} kg/m^2-s. The concentration of nitrogen at the high pressure surface is 4.0 kg/m^3. How far into the sheet from this high pressure side will the concentration be 2.0 kg/m^3. **(3 marks)**

Question 2 (10 marks)

a) Name the three strengthening mechanisms in metals. **(1.5 marks)**

b) Sketch the effect of annealing process (recovery, recrystallization and grain growth) on the grain shape and the strength of cold worked metals. **(2 marks)**

c) FCC metals usually have higher ductility than HCP metals. Why? **(1.5 marks)**

d) A single crystal of metal that has the FCC crystal structure is oriented such that a tensile stress is applied in the [112] direction. If the magnitude of this stress is 2 MPa, compute the resolved shear stress in

i) The (111) $[\bar{1}10]$ slip system.

ii) The $\left(\bar{1}11\right)$ [110] slip system.

iii) Which system is more favorite for slip. **(5 marks)**

Question 3 (8 marks)

A specimen of stainless steel having a diameter of 12.8 mm and a gauge length of 50.8 mm is deformed in tension. Using the stress-strain diagram shown in the Figure, answer the following:

a. Compute the modulus of elasticity

b. The off-set yield strength

c. Determine the tensile strength of this alloy

d. What is the ductility, in percent elongation?

e. Compute the modulus of resilience

f. Determine the lateral strain at a load of 35 kN given that the Poisson's ratio, v is 0.3

g. Compute the strain hardening exponent, n and strength coefficient K in $\sigma_t = K\varepsilon_t^n$.

Question 4 (10 marks)

(a) What is the difference between phase and component? Give examples. **(3 marks)**

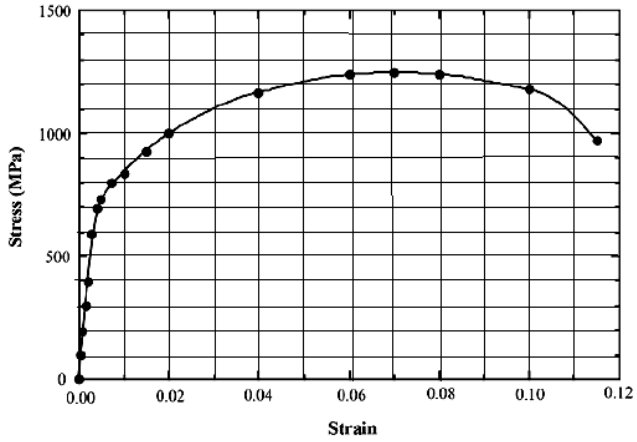
(b) A Cu-50 wt. %Ni alloy is heated to the liquid phase and then cooled to 1300 ºC, determine:

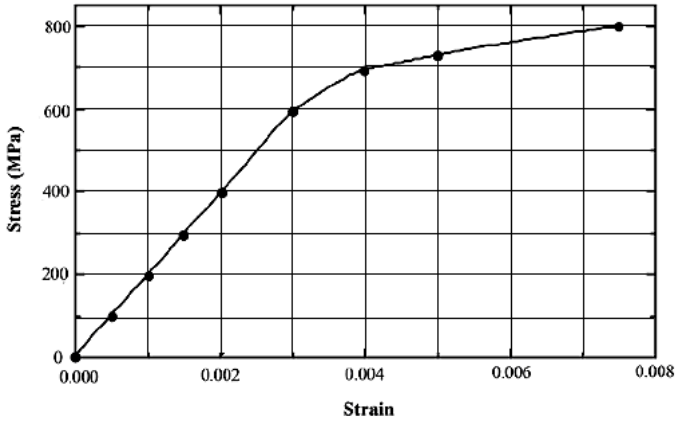
(i) the phases that are present and their chemical composition?

(ii**)** The mass fractions of each phase. Use the given Cu-Ni phase diagram. **(7 marks)**

Chose the correct answer, (5 marks)

1. The stress field for a screw dislocation is ----------
   a. normal stress b. shear stress c. compression stress
2. Diffusion is the phenomenon of material transport by----------
   a. dislocation motions b. atomic motions c. slipping
3. The recovery process ---------- the strength of a cold-worked metal
   a. increases b. decreases c. does not change
4. The slip (motion) of an edge dislocation is ----------to the Burgers vector.
   a. Normal b. parallel c. not related
5. Toughness is the ------- energy absorbed in the tension test.
   a. Elastic b. Plastic c. Total
6. Plastic deformation in metals normally happens by -------.
   a. dislocation slip b. point defects c. grain boundary sliding
7. During plastic deformation dislocation density……..
   a. Increases b. decreases c. does not change
8. The yield strength in metals --------with increasing grain size.
   a. increases b. decreases c. does not change
9. The hardness of metals ---------- with increasing tensile strength.
   a. decreases b. increases c. do not change
10. The strain fields that are caused by edge dislocations are.....
    a. Compression b. tension c. compression and tension


Stress (MPa)
1500
1000
500
0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Strain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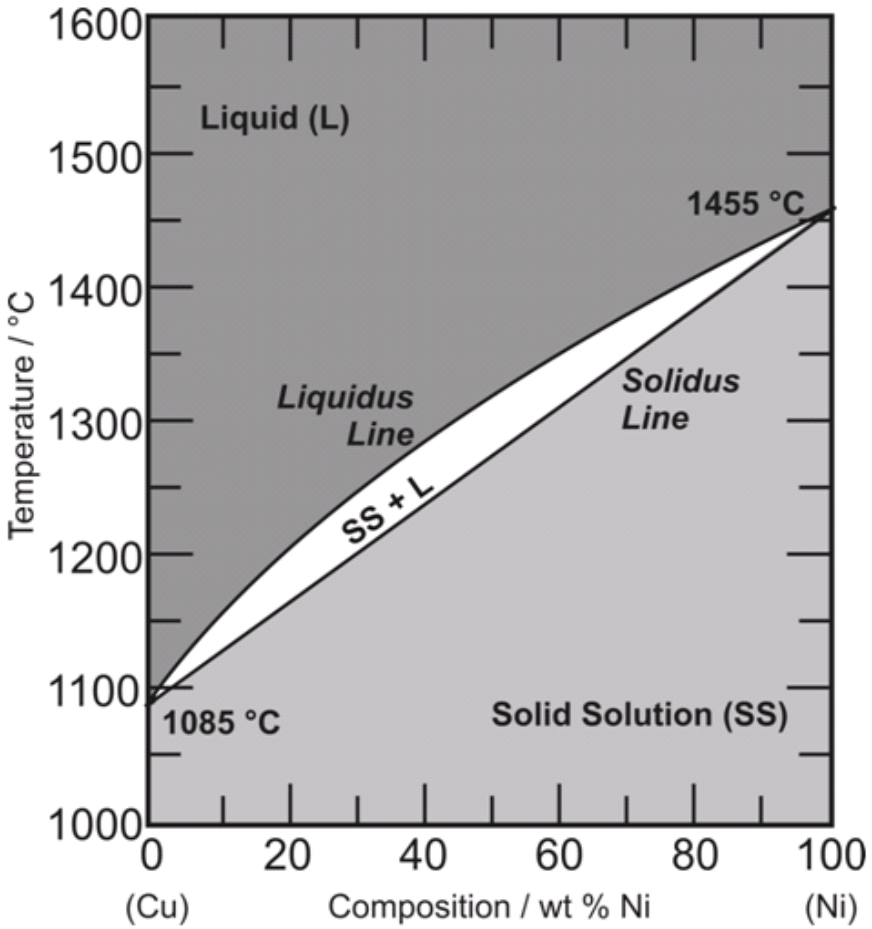
0.002
0.004
0.006
0.008
Strain


Liquid (L)
1455 °C
Liquidus Line
Solidus Line
SS + L
1085 °C
Solid Solution (SS)
Temperature / °C
1600
1500
1400
1300
1200
1100
1000
0
20
40
60
80
100
(Cu)
Composition / wt % Ni
(Ni)

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(1.5 hrs)

Name: **No.:**

Question 1

(b) Classify the following defects as point, line, or planar defect:

2. A screw dislocation
3. A vacancy
4. A low angle boundary
5. An edge dislocation
6. An impurity atom.
7. Self-interstitial atom

(c) State the conditions for complete substitutional solid solubility.

(d) Calculate the fraction of vacancies (fraction of vacant sites) in aluminum at 660 ^{o}C (just below the melting point). The energy for vacancy formation is 0.62 eV/atom and the Boltzmann's constant is 8.62×10^{-5} eV/K.

(e) Calculate the radius of the largest atom that can exist interstitially in FCC iron (atomic radius = 0.1269 nm) without crowding. (Hint: the center of the largest hole is located at (½, 0, 0). Compare the calculated radius to that of the carbon atom of 0.071 nm.

Question 2

(a) In normal motion, the compressive load exerted on the hip joint is 2.5 times body weight.

1. Calculate the corresponding stress (MPa) on an artificial hip implant with cross sectional area of 5.64 cm^2 in a patient weighing 800 N.
2. Calculate the corresponding strain if the implant is made of Ti-6Al-4V alloy which has an elastic modulus of 124 GPa.
3. What is the shear modulus of the alloy? The Poisson's ratio is 0.35.

(b) A single crystal of iron is situated so the tensile load is oriented along [110] crystal direction. If the applied stress is 50 MPa,

1. What will be the resolved shear stress along $[11\bar{1}]$ direction within the (101) plane?
2. If the critical resolved shear stress in the iron single crystal is 31.1 MPa, what is the required tensile stress to cause yielding?

Question 3

(a) The Ni-Cu phase diagram is given below:

1- Draw the cooling curve for an alloy of Ni- 20 wt. % Cu. What are the liquidus and solidus temperature of this alloy?

2- For the alloy of Ni- 40 wt. % Cu, at 1300 ^{o}C:

- Find the equilibrium phases and their chemical composition.
- The weight fraction of the present phases.
- Draw the microstructure of this alloy at 1200 ^{o}C.

(b) Chose the correct answer,

11. Ductility is the ---------strain sustained up to failure
    a. Maximum b. Minimum c. Medium
12. Resilience is the ------- energy absorbed
    a. Elastic b. Plastic c. Total
13. Plastic deformation in metals normally happens by -------.
    a. dislocation slip b. Point defects c. grain boundary sliding
14. During plastic deformation dislocation density……..
    a. increase b. decrease c. do not change
15. Recovery of the cold worked metals …….. their mechanical properties.
    a. increases b. decreases c. does not change

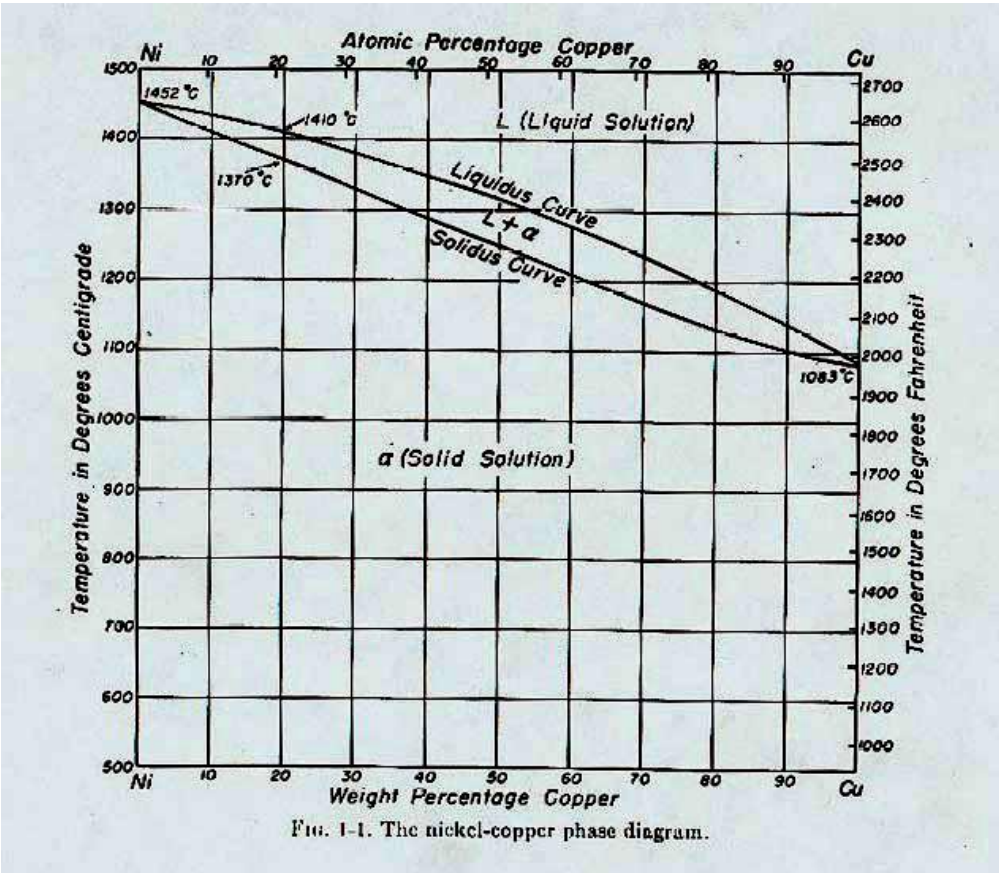

Fig. 1-1. The nickel-copper phase diagram.

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Name: **No.:**

Question 1

a) Identify the types of microscopic imperfections found in crystalline structures.

b) Calculate the number of vacancies per cubic meter in iron at 850 ^{o}C. The energy for vacancy formation is 1.08 eV/atom. Furthermore, the density and atomic weight for Fe are 7.65 g/cm^3 and 55.85 g/mol, respectively.

c) State the conditions for complete substitutional solid solubility.

d) What is the composition, in atom percent, of an alloy that consists of 92.5 wt% Ag and 7.5 wt% Cu? Knowing that, A_{Cu} = 63.55g/mol and A_{Ag} = 107.87g/mol.

Question 2

a) Using intercept method, determine the average grain size, in millimeter, of the specimen which microstructure is shown in Fig. 1. Use at least seven line segments. Estimate the ASTM grain size number for this material. The magnification is 100X.

b) Briefly explain the difference between self-diffusion and interdiffusion.

c) Write Fick's first law in equation form, and define all parameters.

d) **Chose the correct answer,**

16. Ductility is the ---------strain sustained up to failure

    a. Maximum b. Minimum c. Medium

17. Resilience is the ------- energy absorbed in the tension test.

    a. Elastic b. Plastic c. Total

18. Plastic deformation in metals normally happens by -------.

    a. dislocation slip b. Point defects c. grain boundary sliding

19. During plastic deformation dislocation density……..

    a. Increases b. decreases c. does not change

20. During strain hardening in tension test, uniform tue strain is…….. strain hardening exponent n.

    a. Equal to b. less than c. greater than

Question 3

A specimen of stainless steel having a diameter of 12.8 mm and a gauge length of 50.8 mm is deformed in tension. Using the stress-strain diagram shown in Fig. 2 answer the following:

a. Compute the modulus of elasticity
b. Yield strength at a strain offset of 0.002
c. Determine the tensile strength of this alloy
d. What is the ductility, in percent elongation?
e. Compute the modulus of resilience
f. Determine the lateral strain at a load of 35 kN given that the Poisson's ratio, v is 0.3
g. Determine the true stress and true strain at a load of 24.5 kN
h. Using the results obtained in case (g), compute the strain hardening exponent, n given that the constant K is 660MPa.

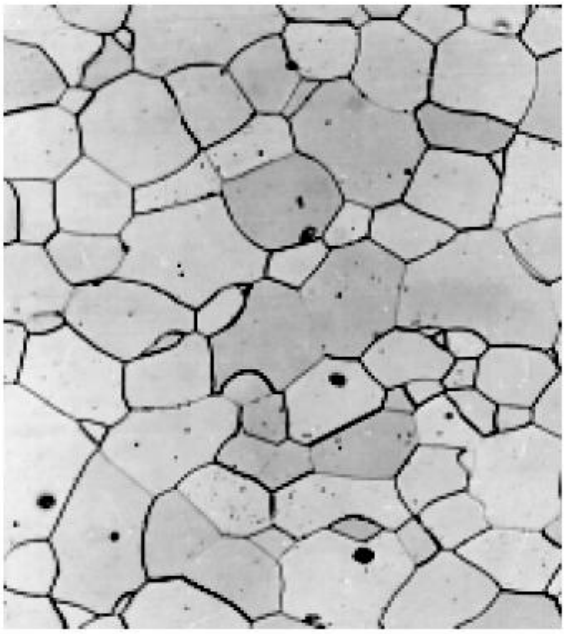
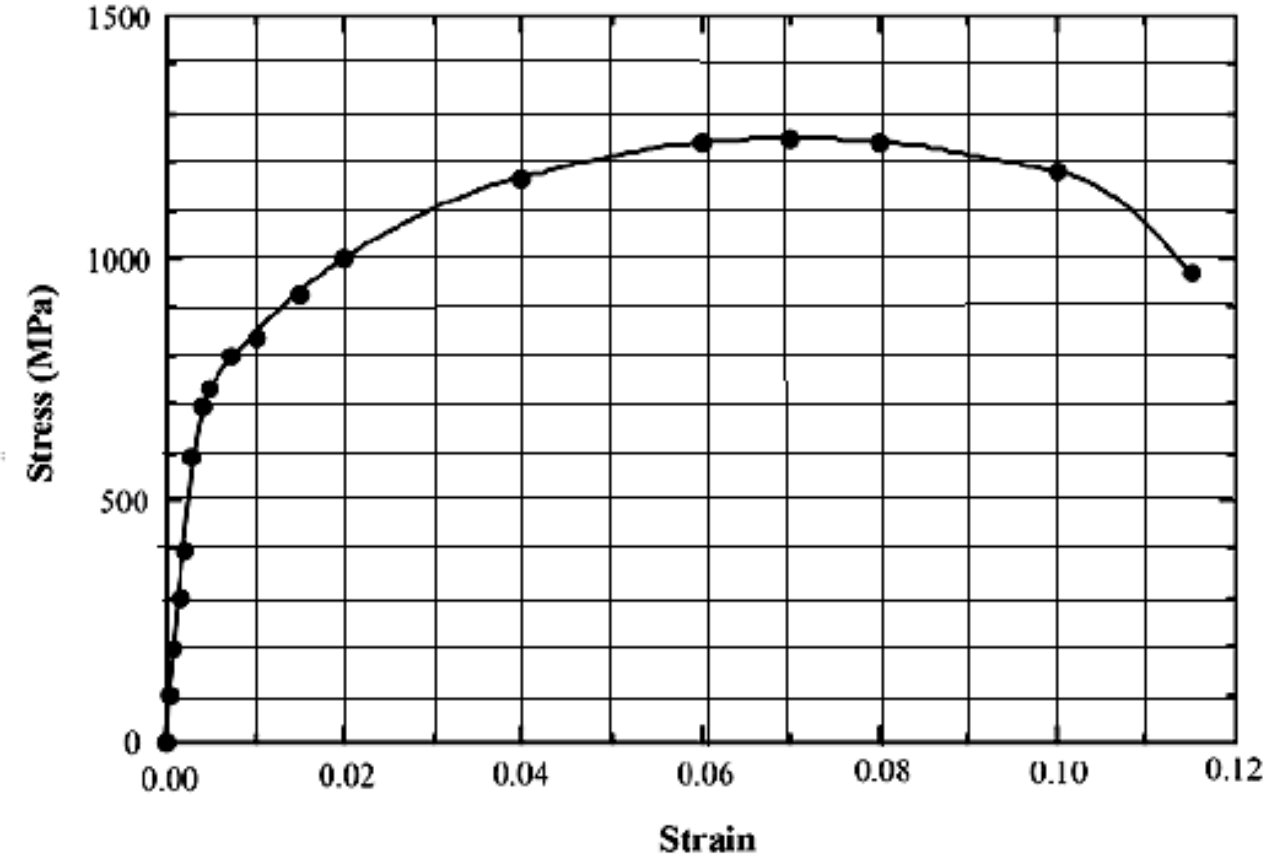


Fig. 1


1500
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Stress (MPa)
0.00
0.02
0.04
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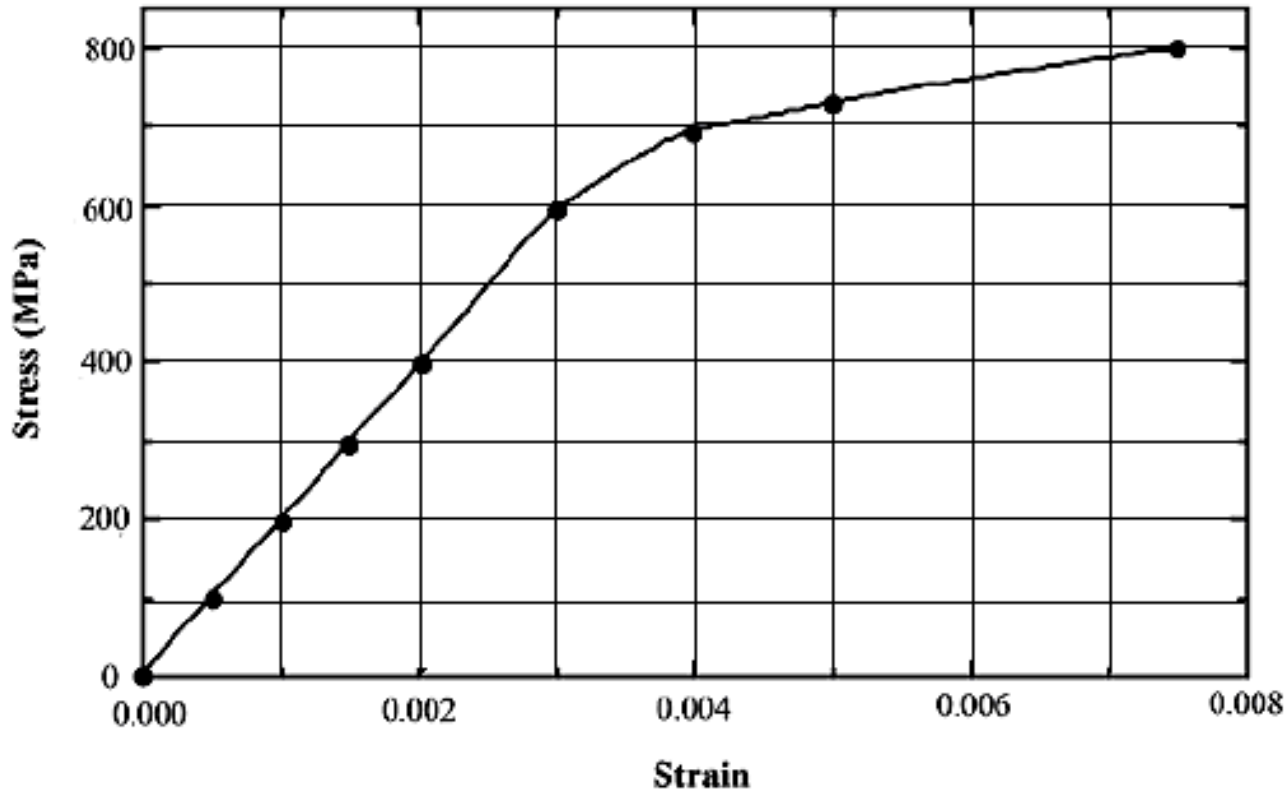
0.12
Strain


800
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400
200
0
Stress (MPa)
0.000
0.002
0.004
0.006
0.008
Strain

Fig. 2

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Problem 1

d) Explain briefly the strengthening mechanisms in metals.

e) Explain by drawing the steps of annealing, (recovery, recrystallization and grain growth) and its importance.

f) Explain why? Some metals, (for example, Lead ($T_{melting}$=327 ^{o}C) are hot worked when deformed at room temperature.

g) A single crystal of metal that has the FCC crystal structure is oriented such that a tensile stress is applied in the [112] direction. If the magnitude of this stress is 2 MPa, compute the resolved shear stress in

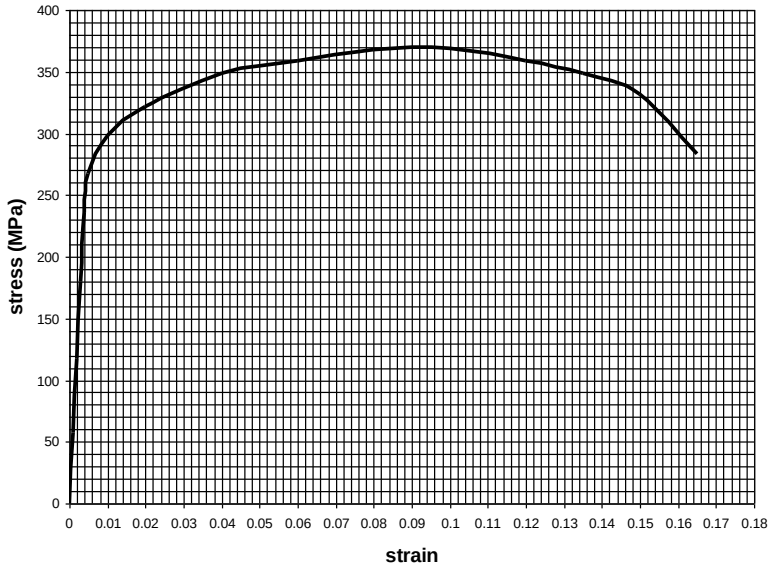
iv) The $[\bar{1}10]$ direction on (111) plane.

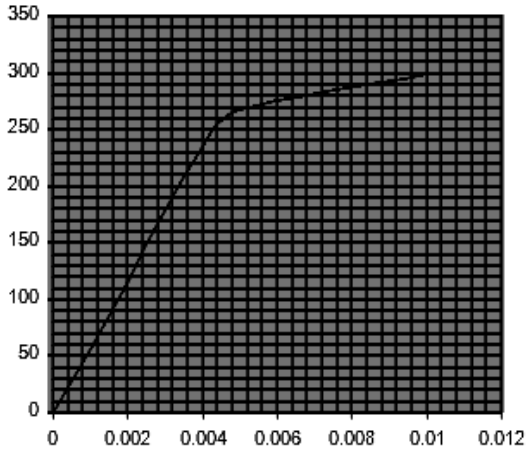
v) The [110] direction on $\left(\bar{1}11\right)$ plane.

Which system is possible slip system?

Problem 2

A cylindrical specimen of aluminum having a diameter of 12.5 mm and a gauge length of 50 mm and a poisson ratio (ν) of 0.3 has the stress strain behavior shown in the figure. Use the stress strain diagram to answer the following,



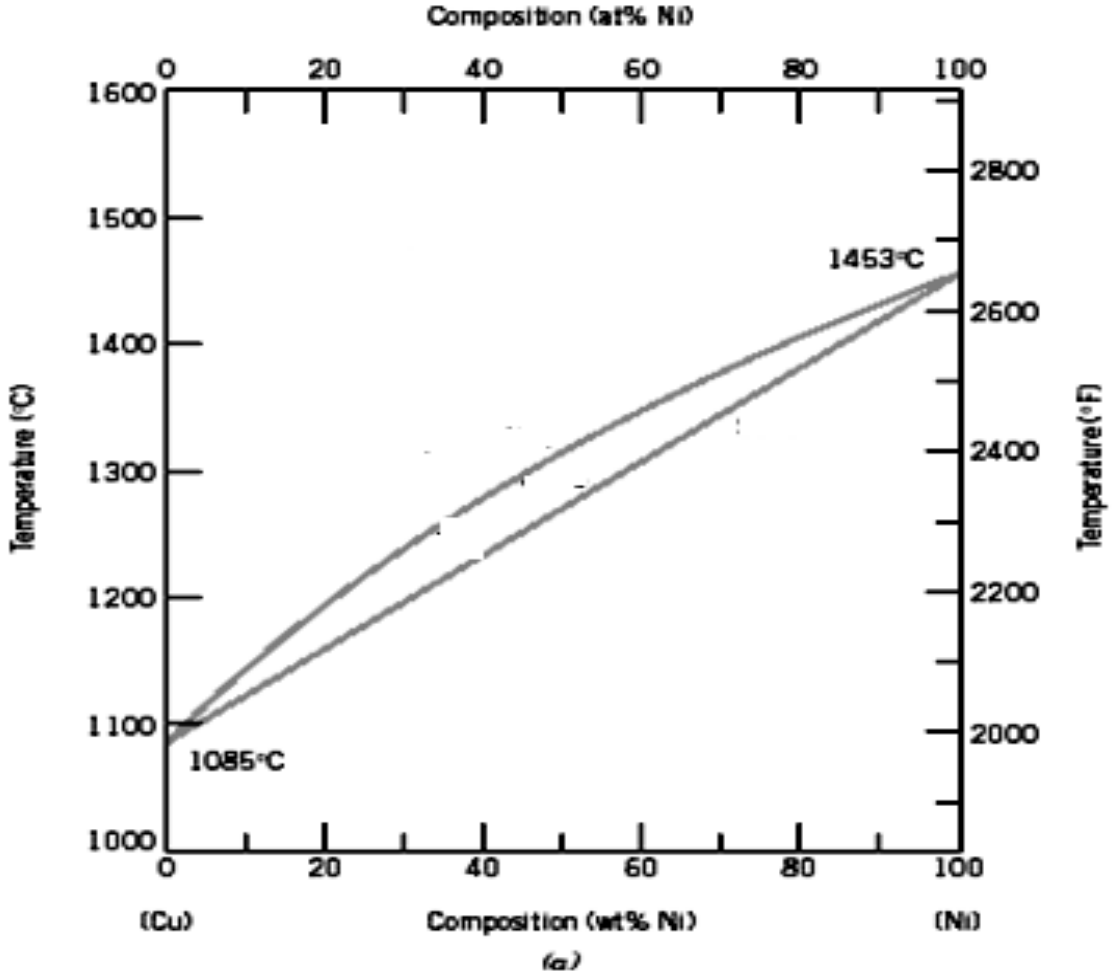


a) Compute the modulus of elasticity.
b) Determine the yield strength at an offset strain of 0.002(show the result in the graph)
c) What is the ultimate tensile and fracture strength?
d) If the tensile load of 36816 N is applied, determine the elastic and plastic strain.
e) Determine what would be the final length if the load 36816 N is applied and then released.
f) Calculate the strain hardening exponent (n) and strength coefficient (k).
g) Modulus of resilience

Problem 3

For the Cu-Ni solid solution phase diagram, and for an alloy having a composition of 40wt%Ni – 60 wt% Cu, calculate the following:

a) Name the phases present on the diagram.
b) At 1260 °C what are the phases present and weight fraction of each phase.
c) At what temperature does solidification starts, and what is the chemical composition of the first solid phase to form?
d) At what temperature does solidification ends, and what is the chemical composition of the last liquid prior to complete solidification?



Problem 4

a) Explain briefly two diffusion mechanisms.
b) Explain what is meant by diffusion flux.
c) A sheet of steel 1.5 mm thick has nitrogen on both sides at 1200C and achieved steady state diffusion. The diffusion coefficient of nitrogen in steel at this temperature is 6×10^{-11} m^2/s, and the diffusion flux is found to be 1.2×10^{-7} kg/m^2-s. The concentration of nitrogen at the high pressure surface is 4.0 kg/m^3. How far into the sheet from this high pressure side will the concentration be 2.0 kg/m^3.

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Question 1

(f)

1. Briefly explain the difference between self-diffusion and interdiffusion.
2. Compare interstitial and vacancy atomic mechanisms for diffusion.
3. Briefly explain the concept of steady state as it applies to diffusion.
4. Write Fick's first law in equation form, and define all parameters.

(g) A sheet of steel 2.5 ***mm*** thick has nitrogen atmospheres on both sides at 900 °C and is permitted to achieve a steady-state diffusion condition. The diffusion coefficient for nitrogen in steel at this temperature is 1.2×10^{-10} m^2/s, and the diffusion flux is found to be 1×10^{-7} $kg/m^2.s$. Also, it is known that the concentration of nitrogen in the steel at the high-pressure surface is 2 kg/m^3. How far into the sheet from this high pressure side will the concentration be 0.5 kg/m^3? Assume a linear concentration profile.

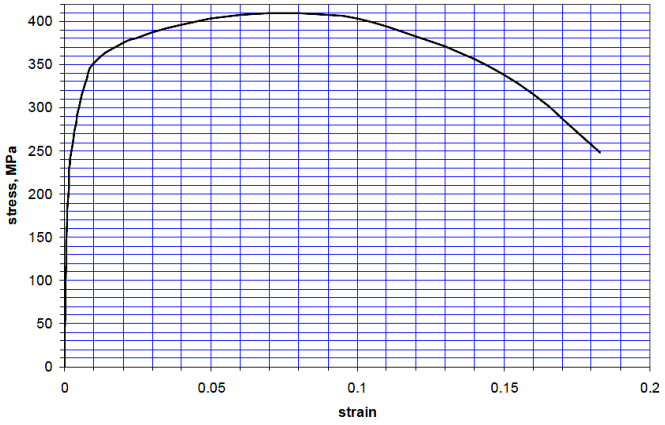
Question 2

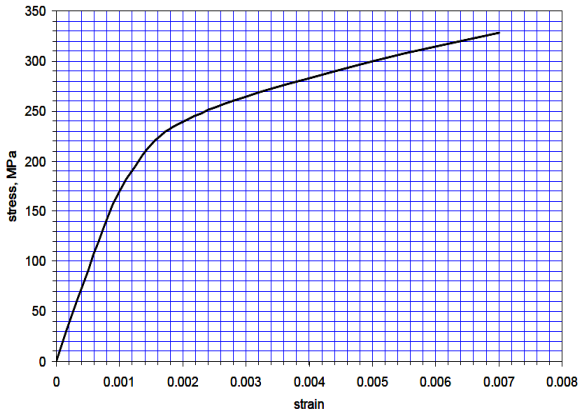
a)

1. Name the two most common hardness-testing techniques; note two differences between them.

b) A specimen of ductile cast iron having a rectangular cross section of dimensions 4.8 mm × 15.9 mm is deformed in tension. Using the stress-strain diagram shown, answer the following:

1. Compute the modulus of elasticity
2. Yield strength at a strain offset of 0.002
3. Determine the tensile strength of this alloy
4. What is the ductility, in percent elongation?
5. Compute the modulus of resilience
6. Determine the lateral strain at a load of 10 kN given that the Poisson's ratio, ν is 0.3
7. Determine the true stress and true strain at a load of 24.5 kN
8. Using the results obtained in case (g), compute the strain hardening exponent, n given that the constant K is 660MPa.





(b) Chose the correct answer,

21. Ductility is the ---------strain sustained up to failure
    a. Maximum b. Minimum c. Medium
22. Resilience is the ------- energy absorbed
    a. Elastic b. Plastic c. Total
23. Plastic deformation in metals normally happens by -------.
    a. dislocation slip b. Point defects c. grain boundary sliding
24. During plastic deformation dislocation density……..
    a. increase b. decrease c. do not change
25. Recovery of the cold worked metals …….. their mechanical properties.
    a. increases b. decreases c. does not change
26. During strain hardening in tension test, uniform tue strain is…….. strain hardening exponent n.
    a. Equal to b. less than c. greater than

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Name: **No.:**

Question 1 (7 marks)

h) Briefly explain the difference between self-diffusion and interdiffusion. **(2 marks)**
i) Write Fick's first law in equation form, and define all parameters. **(2 marks)**

j) A sheet of steel 1.5 mm thick has nitrogen on both sides at 1200C and achieved steady state diffusion. The diffusion coefficient of nitrogen in steel at this temperature is 6×10^{-11} m^2/s, and the diffusion flux is found to be 1.2×10^{-7} kg/m^2-s. The concentration of nitrogen at the high pressure surface is 4.0 kg/m^3. How far into the sheet from this high pressure side will the concentration be 2.0 kg/m^3. **(3 marks)**

Question 2 (13 marks)

e) Explain briefly the strengthening mechanisms in metals. **(2 marks)**
f) Explain by drawing the steps of annealing, (recovery, recrystallization and grain growth) and its importance. **(3 marks)**
g) Do all metals have the same slip system? Why or why not? **(2 marks)**

h) A single crystal of metal that has the FCC crystal structure is oriented such that a tensile stress is applied in the [112] direction. If the magnitude of this stress is 2 MPa, compute the resolved shear stress in

vi) The $[\bar{1}10]$ direction on (111) plane.

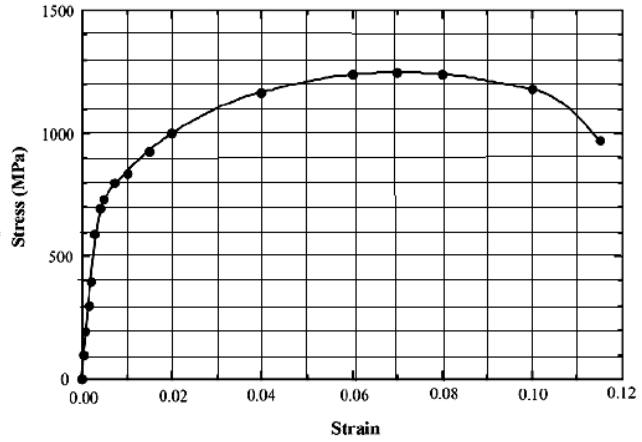
vii) The [110] direction on $\left(\bar{1}11\right)$ plane. **(6 marks)**

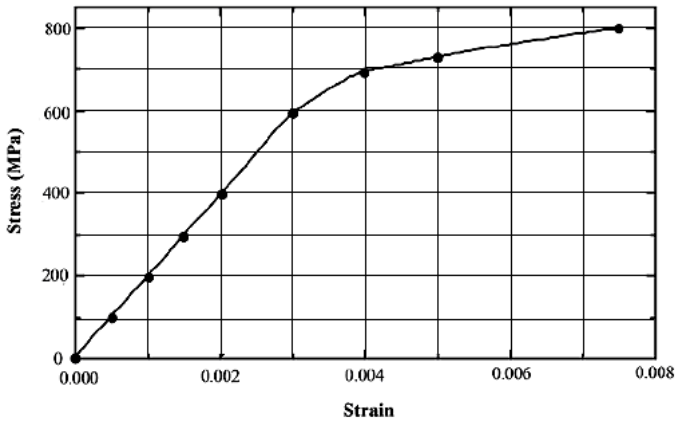
Question 3 (8 marks)

A specimen of stainless steel having a diameter of 12.8 mm and a gauge length of 50.8 mm is deformed in tension. Using the stress-strain diagram shown in Fig. 2 answer the following:

i. Compute the modulus of elasticity
j. Yield strength at a strain offset of 0.002
k. Determine the tensile strength of this alloy
l. What is the ductility, in percent elongation?
m. Compute the modulus of resilience
n. Determine the lateral strain at a load of 35 kN given that the Poisson's ratio, *v* is 0.3
o. Determine the true stress and true strain at a load of 24.5 kN

p. Using the results obtained in case (g), compute the strain hardening exponent, *n* given that the constant *K* is 660MPa.

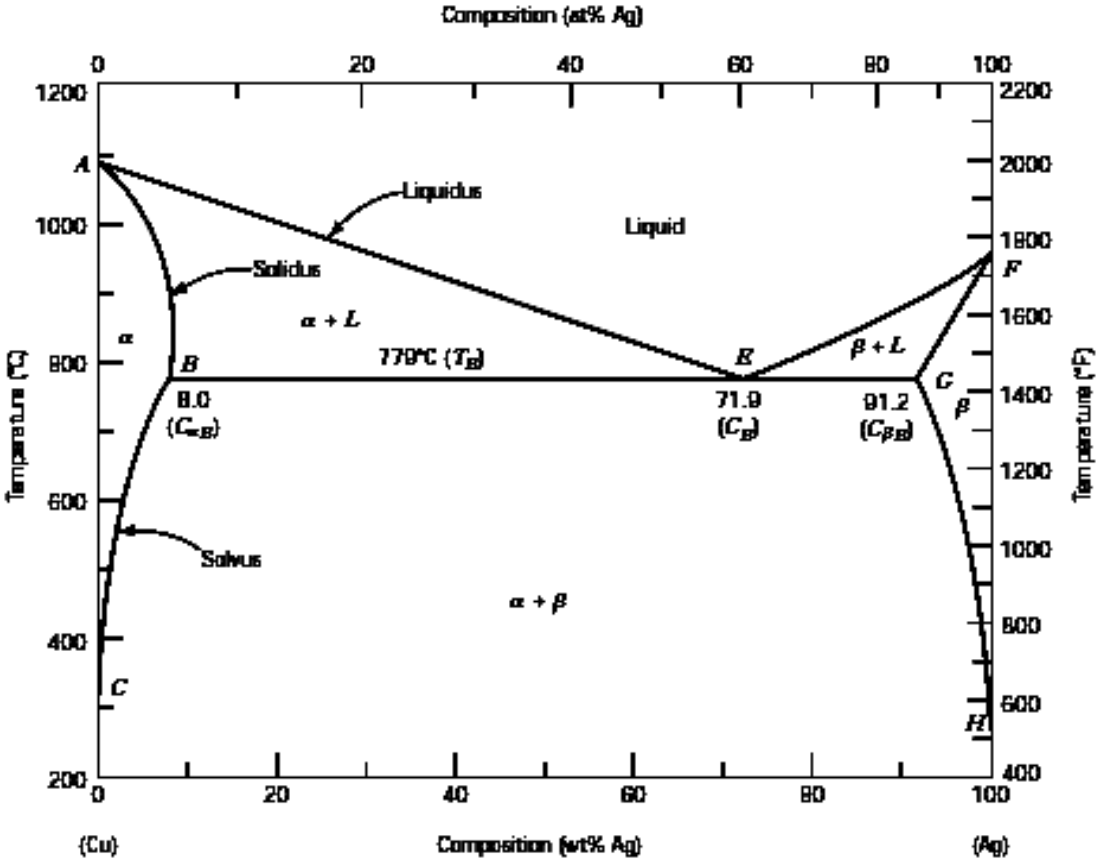




Question 4 (7 marks)

(h) What is the difference between phase and component? Give examples. **(2 marks)**

(i) A 9.8 Kg of Cu-Ag alloy containing 90 wt% Ag–10 wt% Cu is heated to the liquid phase and then cooled to 600 ºC, determine (a) The phases that are present? **(**b**)** The mass fractions and composition of each phase. Use the given Cu-Ag phase diagram. **(5 marks)**



e) <u>Chose the correct answer,</u> (5 marks)

27. Screw dislocation caused by ----------
    a. Normal stresses b. Shear stresses c. Mixed
28. Diffusion is the phenomenon of material transport by----------
    a. dislocation motions b. atomic motions c. slipping
29. The time dependent elastic behavior is known as ----------
    a. elasticity b. plasticity anelasticity
30. The ratio of relative contraction to the expansion strain or transverse strain to the axial strain is called----------
    a. shear modulus b. modulus of resilience c. poisson's ratio
31. Resilience is the ------- energy absorbed in the tension test.
    a. Elastic b. Plastic c. Total
32. Plastic deformation in metals normally happens by -------.
    a. dislocation slip b. Point defects c. grain boundary sliding
33. During plastic deformation dislocation density……..
    a. Increases b. decreases c. does not change
34. Eutectic composition alloys have ……..melting temperature compared to their parent metals.
    a. less b. higher c. same
35. The ability of the metal to plastically deform depends on the ability of the……..
    a. Dislocation to move b. restricting or hindering dislocation c. grain boundary to slid
36. The strain fields that are exist around dislocations is.....
    a. Strain rate b. plain strain c. lattice strain